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OFFSHORE SUPPLY VESSEL TO BUOY TENDER CONVERSION DESIGN  
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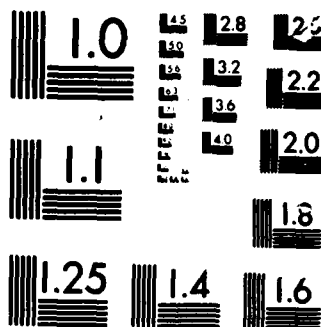
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Report No. CG-D-6-86

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CONVERSION DESIGN

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MARCH 1986

FINAL REPORT

Prepared for:

U.S. Department of Transportation  
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16. Abstract  A typical Offshore Supply Vessel (OSV) was evaluated to determine if the ship could be converted into a buoy tender to be used by the United States Coast Guard. Technical analysis was made of the ship's operating and engineering capabilities. Keeping the hull form the same, the internal arrangement of the converted design was altered to meet the new design requirements of the buoy tender. The preliminary analysis shows that the OSV can be converted into a useful buoy tender with limited multi-mission capabilities. Future studies are needed to assess the risks involved.					
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## INTRODUCTION

The United States Coast Guard operates two major classes of buoy tenders: 180 ft ocean going tenders (WLB), and 157 ft coastal tenders (WLM). These ships are required to perform numerous Coast Guard missions in addition to their primary mission of servicing navigational aids. Presently, there are 28 WLB's and 13 WLM's in service. The WLB fleet was built from 1942-44, while the WLM fleet was constructed in the late 1960's. The projected service life for these ships was 25 years. Several of these tenders have undergone a service life extension yard period, yet many of these ships are fast approaching the end of their service lives. The Coast Guard is currently assessing the options available for replacing these aging ships.

The solution of initiating a new construction acquisition program may or may not be feasible in light of the austere budget forecasts for the Coast Guard. One alternative to new construction is the conversion of an existing ship. A candidate vessel for conversion is the oil industries' Offshore Supply Vessel (OSV). This report explores the feasibility of converting a typical OSV into a Coast Guard buoy tender.

The design requirements for the conversion were obtained from reports published by the Office of Navigation. The design requirements are listed in Table 1.



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From the established design requirements, a list of specific design elements was generated in order to assess the suitability of a typical OSV hull form and its existing equipment for buoy tending. The design elements that needed to be addressed at this stage of the design are contained in Table 2.

The determination of a design element's ability to meet at least the minimum performance requirements was guided by an established design philosophy. This philosophy was developed, with guidance from Commandant G-DMT, by prioritizing the decision influencing criteria. The design philosophy is contained in Table 3. At each stage of this conversion effort, the design philosophy was consulted in order to resolve any uncertainty in our decision making process.

## OSV-BOUY TENDER CONVERSION

DESIGN REQUIREMENTS	THRESHOLD	GOAL
PAYLOAD		
FUEL	33.5 LT	33.5 LT
WATER	56 LT	56 LT
CARGO	50 LT	50 LT
CRANE LIFT CAPACITY	10 LT	20 LT
SPEED	12KT	16 KT
RANGE @ 12.5 KTS	1000 NM	4000 NM
ENDURANCE PERIOD	21 DAYS	21 DAYS
STABILITY		
FLOODABLE LENGTH INTACT	ABS RULES USN STDS	2 COMPARTMENT USN STDS
SEAKEEPING		
CONDUCT BUOY OPS	SEA STATE 3	SEA STATE 4
OUTFIT		
26 FT BOAT	MOTORSURF BOAT	RHIB
14 FT BOAT	RHIB	RHIB
DRAFT MINIMUM		14 FT
FREEBOARD	5 FT	7 FT
ICEBREAKING RAM	14 IN 2 FT	18 IN 3 FT
LOW SPEED TURN	200 FT	MINIMUM
DECK AREA	1600 FT <sup>2</sup>	1600 FT <sup>2</sup>
HABITABILITY	USN STDS	CG PRACTICE
MANNING 5 OFF, 3 CPO, 40 EP	48	48
ARMAMENT	3-.50 CAL 1.5 LT AMMO	3-.50 CAL 1.5 LT AMMO

Table 1



## DESIGN ELEMENTS

- 1) Main Propulsion
  - Develop speed-power curve
  - Assess suitability of current power plant
  - Check range/fuel consumption
- 2) Auxiliary Machinery
  - Determine power and weight for electrical generators
  - Fresh water requirement, evaporator
  - Hot water requirement
  - Refrigeration/freezer
  - HVAC
- 3) Floodable Length
  - Develop floodable length curve
- 4) Arrangements
  - Increase habitability functions
  - Locate newly required spaces
  - Weight statement
- 5) Structural Modification
  - Assess cargo deck strength for buoy handling
  - Ice strengthening to meet ABS rules and design requirements.
  - Crane foundation
- 6) Static Stability
  - KG determination
  - Heeling stability tests
- 7) Maneuvering
- 8) Motions/Seakeeping
  - Performance indicators

DESIGN PHILOSOPHY

In order to perform a logical and consistent decision making process, a prioritized listing of design criteria was established as follows:

- 1) Design for minimum acquisition, operation, and maintenance costs.
- 2) Design for minimum technical risk by making use of operationally proven components and subsystems wherever possible.
- 3) Design to meet or exceed naval habitability standards.
- 4) Design for optimum operational capability in the primary mission of aids to navigation maintenance.
- 5) Design to meet or exceed ABS rules for hull strength.
- 6) Design to meet or exceed naval compartment subdivision criteria.
- 7) Design for mission flexibility. In addition to the primary mission, the vessel should be capable of limited operations as a search and rescue, law enforcement, and icebreaking platform.

Table 3

GENERAL DESCRIPTION

Offshore Supply Vessels (OSV) are designed primarily for the activities relating to the oil drilling industry. These vessels serve as shuttle vehicles between land bases and drilling platforms carrying work crews, food, water, and equipment. The often harsh nature of the environment in which they operate demands that these vessels be inherently stable. OSV's are designed with the capability of carrying up to 500 tons of cargo on deck, or up to 500 tons of liquid and dry drill mud in the hold, or a combination of the two. There are generally accomodation for 20-25 people, but the required crew size is only six or seven. The conversion design was based upon a typical 165 ft OSV with the following principal characteristics:

LOA	165.0 ft
Beam	38.0 ft
Depth	13.5 ft
Disp (full load)	1250 LT
Draft	11.5 ft
Disp (light ship)	600 LT
Propulsion	2200 SHP Twin screw
Bow Thruster	340 hp

The deckhouse is relatively high and located far forward. There is a large open deck work area which extends nearly two-thirds the length of the ship from the deckhouse to the stern. The hull is of chined construction with a double chine forward faired into a single chine amidships faired back to a double chine in the stern. The decks have no camber. Appendix 1 contains a profile, lines drawing, and a table of offsets for a typical OSV.

The hull of an OSV is comprised mainly of tanks that carry fuel, ballast water, and liquid and dry drilling mud. The engine room, steering gear room, and bow thruster space are also located in the hull. The total capacities and volumes of the tanks are as follows.

Fuel	116 LT	5,000 ft <sup>3</sup>
Ballast	630 LT	22,680 ft <sup>3</sup>
Mud	500 LT	8,372 ft <sup>3</sup>

#### ARRANGEMENTS

The arrangements for a typical OSV prior to the proposed conversion are contained in Appendix 2. The major arrangement task was increasing the berthing areas to accomodate the new complement of 48. Consistent with the design philosophy, minimal structural changes to the vessel were sought to reduce cost. This resulted in the original

design arrangement dictating the overall size of many of the compartments. To determine possible compartment locations minimum volumes for required spaces in the new design were first computed.

Volume calculations for habitability spaces were based on similar ship data from past Coast Guard designs, and OPNAV Instruction 9640.1 requirements. In most instances the minimum space requirements, as outlined in the OPNAV Instruction, were easily achieved. Appendix 3 contains the detailed area breakdown.

A comparison of required and available tank volumes revealed that the mud tanks and several ballast tanks could be converted into habitability spaces and still leave enough tankage to meet the liquid load requirements. Converting tanks into inhabitable spaces offered the only course to gain needed volume from a design so severely limited in volume.

The new arrangements were designed to conform to the bulkhead subdivision of a typical OSV to minimize cost. The floodable length section of this report examines the consequences of this decision on damaged stability. In the hold area, removal of the dry mud tanks provided enough usable volume to arrange a cold storage compartment, two berthing compartments for 12 and 18 men, and a head/shower facility large enough to accommodate the associated crew. The liquid mud tanks were replaced with an engineering work space and dry stores. Forward ballast tanks were converted

into a C3I space and the laundry, and two aft ballast tanks became general and engineering stores.

The main deck enclosure was lengthened 22 ft to provide an enlarged mess deck and galley and to house the deck gear stowage locker. The two original 4-man berthing compartments were converted into a single 12-man berthing area. CPO quarters with an attached head and a separate lounge/mess were added.

The 01 level was lengthened 5.5 ft and converted into officers country. A pair of two man staterooms share a common head and shower facility, while the CO's stateroom has a private head adjoining it. The 02 level was lengthened 8 ft to increase the bridge area and improve visibility to the stern for buoy operations.

Increasing the length of the superstructure was the cheapest way to increase the total volume of the OSV. The deck space lost is minor compared to the gain in living space.

An electric single point crane with a 44 foot reach was positioned 125 ft aft of the bow, at frame 63. The centerline location provides 1900 ft<sup>2</sup> of deck space forward of the crane and allows for buoy operations from either side of the ship.

Once all the general arrangements were completed, the impact on the static stability of the converted design had to be assessed.

WEIGHT

Weight calculations used a typical OSV in the light ship condition as a baseline for displacement, longitudinal and vertical centers of gravity, and draft. A detailed structural weight statement was not available for reference. To estimate the new displacement, specific items for removal or addition were identified on the general arrangement drawings. The weight of each component was estimated, and the center of gravity for the component was assigned to its centroid. For this conversion an estimated 20.3 tons were removed from and 109 tons were added to the light ship displacement. The majority of the weight falls into SWBS weight group 100.

An accounting technique recorded the weight and center of gravity for each component added or removed. Weights and moments were then summed and the net change was applied to the baseline OSV to obtain the converted design's lightship displacement, center of gravity, and trim. The converted design's light ship displacement in the unballasted condition is 612 LT with a draft of 6.6 ft and a trim of 62 in by the stern. The same procedure was also carried out for the converted design in the full load and minimum operating (1/3 of all consumables remaining on board) conditions. Appendix 4 contains the detailed weight removal and addition calculations.

STRUCTURAL CHANGES

To determine if any structural changes were necessary, the following areas were examined: 1) structural support for concentrated loads on deck, 2) structural support for the crane foundation, 3) ice strengthening to comply with ABS rules.

The deck plating in the vicinity of the buoy deck is 0.375 in thick and is capable of withstanding operating loads of 540 lbs/ft<sup>2</sup> and maximum loads up to 1250 lbs/ft<sup>2</sup>. This is adequate to meet the anticipated loads imposed by the buoys and sinkers.

To assess the structural changes needed to support the crane and its foundation, similar ship data was used to estimate the additional structural weight. It was assumed that this additional structure could be added without noticeably interfering with the below deck spaces. At this stage of the design only a weight estimate was calculated. Further engineering of the crane foundation would be required.

The ability of the converted design to meet the icebreaking mission requirement is severely limited. The mission requirements place this vessel in Class IAA under the ABS rules for ice strengthening. Class IAA is for full winter operation in solid ice of thickness of about 1 meter. The other ice classes are for operation in open broken ice, or small ice floes. Regardless of ice class,



the new design does not meet the minimum requirements for frame thickness as specified by ABS. Minimum frame thickness is stated as 0.39 in and typical frame thicknesses are only 0.3125 in. The ice belt requirement for the Class IC operation calls for a plating thickness of 1.4 in of mild steel or 0.82 in of HY 80. To meet the requirements for even Class IC operation would require a major and costly structural change to the hull. Appendix 5 contains the detailed structural calculations.

In addition to the structural deficiencies the typical OSV hull design is not suitable for icebreaking. ABS specifies a bow angle of between 25-35 degrees. The typical OSV has a bow angle of approximately 55 degrees. The chined hull form and exposed screws also do not lend themselves well to ice operation.

ENGINEERING CHARACTERISTICS

An evaluation of all the engineering components aboard the OSV was conducted. Using the design requirements as a guide, the required shaft horsepower, electrical generating capacity, and other auxiliary systems were sized. Since minimizing conversion cost was the top priority of the design philosophy it was highly desirable to retain any present engineering system if it met the threshold of performance as specified by the operating requirements.

SPEED AND POWER-MAIN PROPULSION ENGINES

The design requirements for the conversion established threshold and goal speeds of 12 and 16 knots. A 160'-180' OSV generally has 2,000-3,000 SHP installed. To determine the powering requirements at various speeds, Neveitt [1] provides a method of obtaining the speed-power curve for an OSV hull form of standard proportions. The speed-power curve indicates that 2,000 SHP yields a speed of approximately 13.5 knots. Similar OSV hulls with displacements of 1,275-1,300 LT advertise an operating speed of 12 knots at 2,100 SHP. This lends confidence to the calculation of a higher speed at a lower displacement. Appendix 6 contains the detailed calculations.

Twin Detroit Diesel GM 16V149 marine engines developing 1,060 HP each, are commonly found aboard existing OSV's for main propulsion. Engines of this size would provide the required shaft horsepower to obtain speeds of 12.5-13 knots. This is within the acceptable limits of the design requirements.

It should be noted from the speed-power curve that an exponential increase in SHP is required to achieve any speeds in excess of 14 knots. The goal speed of 16 knots would not be attainable without re-engining the OSV with approximately 4,000 SHP. The design philosophy of minimizing conversion cost dictates that the existing main engines remain installed since they do provide the threshold speed of 12 knots.

As a consequence of not repowering the conversion, the associated propulsion components as originally installed need not be altered. The engine controls, propellers, shafts, steering gear, and rudders all comply with various ABS/USCG specifications.

#### RANGE AND FUEL CONSUMPTION

All calculations were based on a Detroit Diesel 16V149 power plant. The existing fuel oil tank capacity for an OSV is approximately 106 tons. Using the goal range of 4,000 NM, a Specific Fuel Consumption of 0.42 lb/hp-hr, a speed of 12.5 kts, and 2,000 HP, a calculation was performed in

Appendix 7 to determine the tankage required. A fuel oil tank capacity of 120 LT would be required to meet the design's 4,000 NM range requirement. An additional 33.5 LT of fuel is also required to meet the cargo requirement. The total required fuel capacity of 153.5 LT exceeds the installed fuel oil tankage by 47.5 LT. This additional tankage can easily be made up, since there are several empty ballast tanks that could be converted into additional fuel storage tanks. Two forward ballast tanks, with capacities of approximately 36 LT each, could easily be converted to fuel storage with a minimum of piping changes. This would increase the vessel's total fuel oil capacity to 178 LT, which would be more than adequate to achieve the operating range of 4,000 NM and provide a fuel oil payload of 33.5 LT.

A liquid loading plan for the fuel oil tanks is as follows:

24-1-F	36.8 LT
24-2-F	36.8 LT
74-1-F	41.25 LT
74-2-F	41.25 LT
FD DAYTANK #1	12.3 LT
FD DAYTANK #2	12.3 LT

#### ELECTRICAL GENERATING SYSTEM

Following the design philosophy of selecting operationally proven components, the electrical requirement evaluation was done using similar ship data. Conversion components requiring an increase in electrical generating capacity include the buoy deck crane, C3I, and all upgraded auxiliary systems. Similar ship data and SNAME T & R

Bulletin 3-27, indicated that two generators rated at 255 KW each would be adequate to meet the increased electrical demands of the converted design. Appendix 8 contains these calculations. This increased load would exceed the generating capacity of a typical OSV's two generators, each capable of producing approximately 100 KW. Replacement or upgrading the generating system aboard a typical OSV would be necessary.

In studying the alternatives for increasing the electrical generating capacity of the vessel, a major concern was the size and weight of the replacement generators. Enlarging the engine room to accomodate larger sized generators was to be avoided, if at all possible, due to concern for adverse effects on floodable length.

Many OSV generating systems use two GM 8V 71 diesels powering Delco 208/120 V generators rated at 99 KW at 1,200 RPM. The Diesel and Gas Turbine Catalog, 1985 [2] indicates that the same prime movers when turbocharged are rated at 275 KW at 1,800 RPM. The increase in size and weight due to the addition of a turbo charger is very little. With only a slight weight addition due to the larger electrical generators required existing space allocations are sufficient.

AUXILIARY SYSTEMS

An evaluation of the existing auxiliary systems aboard a typical OSV identified several that would require upgrading or replacement as a result of the increased crew size. Doubled accommodations placed increased demands upon refrigeration, hot water, potable water, heating, air conditioning, and ventilation.

The amount of frozen and chill space required for a crew of 48 on a vessel with a 21 day endurance was calculated following US Navy requirements. The figure used in this study was  $3.65 \text{ ft}^3/\text{day}/\text{man}$ . It was estimated using similar ship comparisons that for a volume of  $891 \text{ ft}^3$ , 0.65 tons of refrigeration equipment would have to be installed.

The increased demand for hot water onboard could not be handled by the existing hot water system alone. The typical hot water system consists of a 52 gallon electrically heated tank located in the crew's head. To meet the increased demand one additional electric hot water tank with a capacity of 52 gallons would be installed in the second crew's head.

The typical OSV has ample fresh water storage capacity to meet the requirements of the converted design. While the tank capacities for the storage of fresh water are adequate, the capability of making fresh water must also exist. An evaporator with a capacity of 2,000 gallons/day

(40gal/man/day) would have to be installed. The estimated added weight for this system is 1.2 tons.

To comfortably maintain the climate in the expanded living quarters the HVAC system would have to be upgraded. Based on existing ship data, an additional 6.7 tons of equipment would be added. This equipment would include air conditioning compressors, electric heaters, fans and ventilation piping.

## OPERATIONAL CAPABILITIES

To assess the converted design's intact and damage stability, the following criteria were examined:

- 1) Intact stability
  - a) weight balance calculations to determine KG, list, and trim.
  - b) Navy Design Data Sheet DDS 079-1 stability criteria for 100 kt beam wind, weight over the side, and high speed turns.
  - c) USCG static towline pull criteria.
  - d) limiting drafts.
- 2) Damage Stability
  - a) floodable length calculations.
  - b) trimlines after flooding specific compartments.

Initial calculations following the weight removal and addition process indicated that the unballasted converted design in the full load condition had a substantial (6') trim by the stern. To correct for this condition, the converted design must operate with the forward ballast tanks filled with approximately 103 tons of water. The weight addition/removal process also balanced transversely. The converted design encounters zero list in normal loading conditions. Appendix 4 contains these calculations.

A summary of the intact stability parameters are as follows:

CONDITION	DISP	KG	GM	GM/B
TYPICAL OSV	1340	12.4	11.5	0.30
CONVERTED DESIGN				
FULL LOAD	1031	11.2	9.3	0.24
MINIMUM OP	853	12.04	10.5	0.29

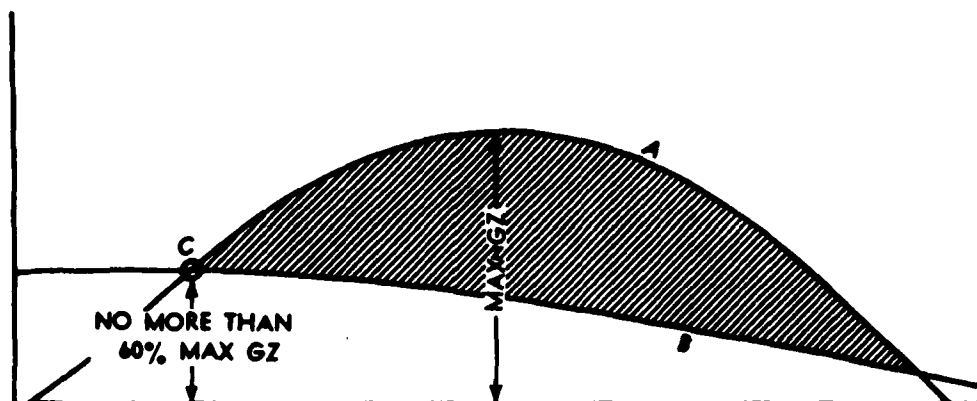


The GM/Beam ratio for the converted design is very high resulting from the removal of the standard deck cargo. The normal design range for the GM/B ratio on a surface combatant is 0.06-0.12. The consequences of having a high GM/B ratio are a very stable ship with a very short roll period. The resulting strong "snap roll" could lead to crew discomfort during open water transits.

#### STABILITY DETERMINATION

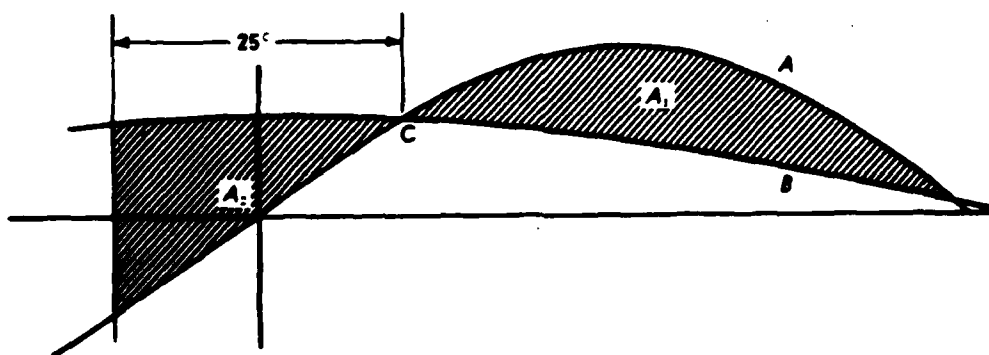
Computer calculations using Ship Hull Characteristic Program (SHCP) were made based on a typical OSV hull form to determine the ship's righting arm at various angles of heel in the full load and minimum operating condition. The righting arm was directly calculated and did not need to be corrected for an assumed KG, since the converted design's KG was known. The total Free Surface Correction was less than 1% of the average righting arm, and thus its influence on the righting arm was ignored.

The converted design's righting arm curves were compared to the heeling arm curves for various conditions. The heeling arm curves were generated using the formula presented in DDS 079-1. The criteria used to judge the intact stability of the converted design for lifting weights over the side, in a high speed turn, and while towing are as follows:



- 1) C - the angle of heel  $< 15^\circ$
- 2)  $RA_C \leq 0.6 \cdot RA_{\max}$
- 3) the area of reserve stability  $A_1 \geq 0.4 \cdot A_t$  total area under the righting arm curve.

The stability criteria for a ship subjected to a 100 knot beam wind and rolling are:



- 1)  $RA_C \leq 0.6 \cdot RA_{\max}$
- 2) the area of residual righting energy  $A_1 \geq 1.4 \cdot A_2$ , where  $A_2$  represents the ship's rolling energy and is limited to 25 degrees beyond the angle of heel.

Exceeding these limiting conditions critically affects the ship's operational capability. An angle of heel beyond 15 degrees interferes with personnel and machinery operations. A heeling arm less than 60% of  $GZ_{max}$  and the requirement that the reserve dynamic stability not be less than 40% of the total righting arm energy insure that an adequate margin is maintained against capsizing.

The stability information for a 20 LT weight hanging 25 feet over the side, a high speed turn, towing operations, and a 100 kt beam wind are tabulated below for the full load and minimum operating condition. Plots and calculations are contained in Appendix 9.

TEST	HEELING ARM	HEEL	$GZ_c$	$0.6 \cdot GZ_{max}$	A1	$0.4 \cdot A1$
FULL LOAD CONDITION:						
20 LT WEIGHT	$0.854 \cdot \cos \theta$	6°	0.8	2.4	147.75	75.34
TOWING	$3.010 \cdot \cos \theta$	18°	2.8	2.4	59.4	75.34
TURN	$1.120 \cdot \cos \theta$	6°	1.0	2.4	136.74	75.34
100 KT WIND	$0.818 \cdot \cos \theta$	7°	0.8	2.4	154.95	56.56
MINIMUM OPERATING CONDITION:						
20 LT WEIGHT	$1.029 \cdot \cos \theta$	7°	1.0	2.4	131.05	70.5
TOWING	$3.66 \cdot \cos \theta$	20°	3.3	2.4	30.2	70.5
100 KT WIND	$1.120 \cdot \cos \theta$	8°	1.0	2.4	136.25	64.40

From these results one can conclude that the conversion meets all the stability criteria except for towing. Based on the equation for the towing heeling arm, the ship has the potential to encounter a dangerous list and does not possess suitable reserve stability to provide an adequate margin against capsizing.

The relatively high towing heeling arm ( $3.66 \cdot \cos \theta$  for the minimum operating condition) results from the following equation:

$$\text{HEELING ARM} = \frac{2 \cdot N \cdot (\text{SHP} \cdot D) \cdot 0.66 \cdot S \cdot h \cdot \cos \theta}{38 \cdot \text{displacement}}$$

N=number of props	2
SHP= shaft horsepower	1,000
D=prop diameter	7 ft
S=stream deflection	0.55
h=shaft to tow bit	11.5 ft
displacement tons	1,031 (full load) 835 (light ship)

The high value of the resulting heeling arm is primarily influenced in this design by its light displacement.

#### DAMAGE STABILITY FLOODABLE LENGTH

Floodable length is the maximum length of any specific compartment which can be flooded to cause a damaged ship to float at a waterline tangent to its margin line. The floodable length at each station along the ship is plotted to produce a floodable length curve. The ordinate of this curve represents the length of ship that may be flooded, for a compartment centered at that length, without submerging the margin line. For a ship to meet a two compartment floodable length criteria, the total length of any two adjacent compartments must be less than the floodable length at their combined center. A one compartment standard requires that only each individual compartment be less than the floodable length at the compartment's center.

The design philosophy emphasizes minimizing cost and places lower emphasis on meeting a specific floodable length criteria. Following the design philosophy, the conversion design was not subdivided to achieve a specific floodable length, but rather, the existing subdivisions were evaluated to determine what type of floodable length criteria the ship satisfied. Where practical and inexpensive, small changes to the ship's subdivision were made to enhance its damage stability. These changes primarily consisted of installing watertight doors in passageways corresponding to the existing transverse bulkheads.

The design threshold for damage stability was determined to be the ABS subdivision rules for ships less than 200 feet in length. The design goal was set to a two compartment requirement.

To meet the threshold, the ship had to have a collision bulkhead not less than 5% of the waterline length aft of the forward perpendicular and watertight bulkheads fore and aft of the engine room. Offshore supply vessels are subject to ABS approval, and are built in accordance with these standards. Therefore, without any major changes, the conversion design would meet the threshold criteria.

To evaluate how close the design approaches the two compartment damage requirement, floodable length calculations were computed using the ship's offsets as input into SHCP. Floodable length calculations were computed for two separate conditions as the maturity of the design

progressed. An average permeability of 0.85 was assumed for both conditions. Data for the two conditions are presented to serve as a reference regarding the effects of deck watertightness and displacement on floodable length. Complete results for both conditions are presented in Appendix 10. The conditions evaluated are as follows:

- 1) Disp=1,275 LT, second deck watertight.
- 2) Disp=1,031 LT, first and second deck watertight.

The floodable length calculations for condition 1 revealed the forward and aft spaces of the converted design would be limited to an average total length of 10 feet, with the maximum allowable compartment being 22 feet in length. Meeting a two compartment criteria for this condition is not feasible; 60% of the ship would be limited to 5 foot compartments. Even meeting a one compartment standard in this condition is not practical, since the main engines are 13 ft long.

Condition 2 floodable length calculations reflect the current design configuration and loading conditions at this stage in the design spiral. In condition 2 the watertight integrity was increased to include the main deck, which is common practice aboard OSV's. As a result, the floodable length curve exhibits the unusual enlarged lengths in the forward portion of the ship due to the increased captured volume available to combat forward flooding. The allowable compartment lengths for the forward 80 ft of the converted

design average 45 feet with the remainder of the ship averaging 25 foot compartments.

Evaluating the final general arrangement plan against the floodable length curve shows that the converted design meets a one compartment standard for all spaces except the engine room. The existing engine room length of 31 ft exceeds the allowable floodable length by 6 ft. Condition 2 thus meets the threshold requirement for floodable length, but falls one compartment short of achieving a one compartment subdivision standard.

#### PROBABILISTIC STABILITY

If the minimum threshold for subdivision is raised to a strict one compartment criteria the current, cost efficient general arrangement should not be abandoned until further research is conducted in the area of probablistic stability. The classical floodable length calculations are based on side shell to side shell flooding, which is not always the case. The field of probabilistic stability examines the probability that damage will occur to a vessel, the location and length of the damage, the depth of penetration, and numerous other factors relating to the vessel's operational status. This topic was researched and a list of references are included should further studies be made in this area regarding the converted design.[3-6]

It should be noted that even though the current design does not meet a strict one compartment subdivision criteria, the presence of wing tanks and the possible addition of a double bottom in the engine room presents definite probabilistic protection from flooding in the classical sense.

### MOTIONS

Seakeeping and motion predictions for this hull form are presented in two forms; a computer generated seakeeping estimate and similiar ship data.

The computer generated seakeeping information is based on the Bales Seakeeping Estimator. The Bales estimator calculates the relative seakeeping performance for a defined hull form using an empirical equation.

The range for the Bales indicator is 0-10, with 10 indicating the best seakeeping performance. The Bales indicator for the conversion design is 8.35, thereby indicating good seakeeping performance. Suggested changes to improve the hull's seakeeping would be to increase the total length and/or decrease the draft. A Bales indicator of 8.35 is high enough not to warrant the cost of changing the hull form to improve seakeeping. Appendix 11 contains the documentation concerning the Bales estimator.



Similar ship data provides a less empirical reference to the conversion design's seakeeping potential. Data from a 190 foot, 1,400 ton offshore supply vessel in sea state four, beam seas is provided in Appendix 11. These data show that the ship encounters a significant rolling condition in this sea state. Transit would be possible, but uncomfortable due to the short roll period resulting from the high GM/B ratio. Buoy operations may be difficult to conduct due to excessive deck wetness resulting from the 4 ft freeboard. While the actual converted design's characteristics would be slightly different, these data present a good estimate of expected responses.

Additional seakeeping estimations are also provided in Appendix 11 for a 150 foot 1,210 ton displacement ship operating in sea states 3, 4, and 6 at five different headings. These data show that propeller emersion and bow slamming will not occur in sea state 4 when operating at speeds up to 10 knots.

## CONCLUSION

In order to draw conclusions as to the feasibility of the conversion design, attention is focused on the success or failure of the converted design to meet the minimum design requirements. As detailed in this report, the converted design would meet all required intact stability criteria except for the towing standard. Through internal rearrangement it would comfortably accommodate the increased crew size. Installation of a deck crane and the existing open deck work area provides the conversion design with the ability to tend buoys. The requirements for carrying food, water, and fuel for a 21 day endurance period are easily met. Other requirements related to speed, range, draft, and payloads are all within the acceptable limits. The design also has a very large weight margin for future growth. Based on these performance criteria the converted design would be capable of carrying out its primary mission of servicing aids to navigation.

The limitations on the converted design are in the areas of ice breaking capability, towing ability, freeboard, volume margin, and most critically in compartment subdivision.

The extensive floodable length calculations presented indicate that a two compartment subdivision standard is impractical and that a one compartment standard could be achieved in all spaces except the engine room. The failure

of the converted design to meet a one compartment standard by a single compartment is the only flaw identified in this report to prevent a typical OSV from performing navigational aid maintenance for the Coast Guard.

The lack of icebreaking capability and the towing inadequacy as defined by the ABS rules and USCG requirements are not deficiencies that would prevent the converted design from fulfilling its primary mission. The effects of failing to meet the minimum freeboard of 5 ft by 1 ft would require more extensive motion and deck wettness studies than were conducted for this report. Table 4 compares the design requirements with the converted design's actual values.

The authors fully recognize that more in-depth analysis of certain topics need to be performed. These areas include crane foundation engineering, auxiliary system piping, HVAC ducting, electrical power distribution, review of buoydeck strength for impact loading, and the possible application of probablistic stability techniques to assess floodable length compartment subdivision.

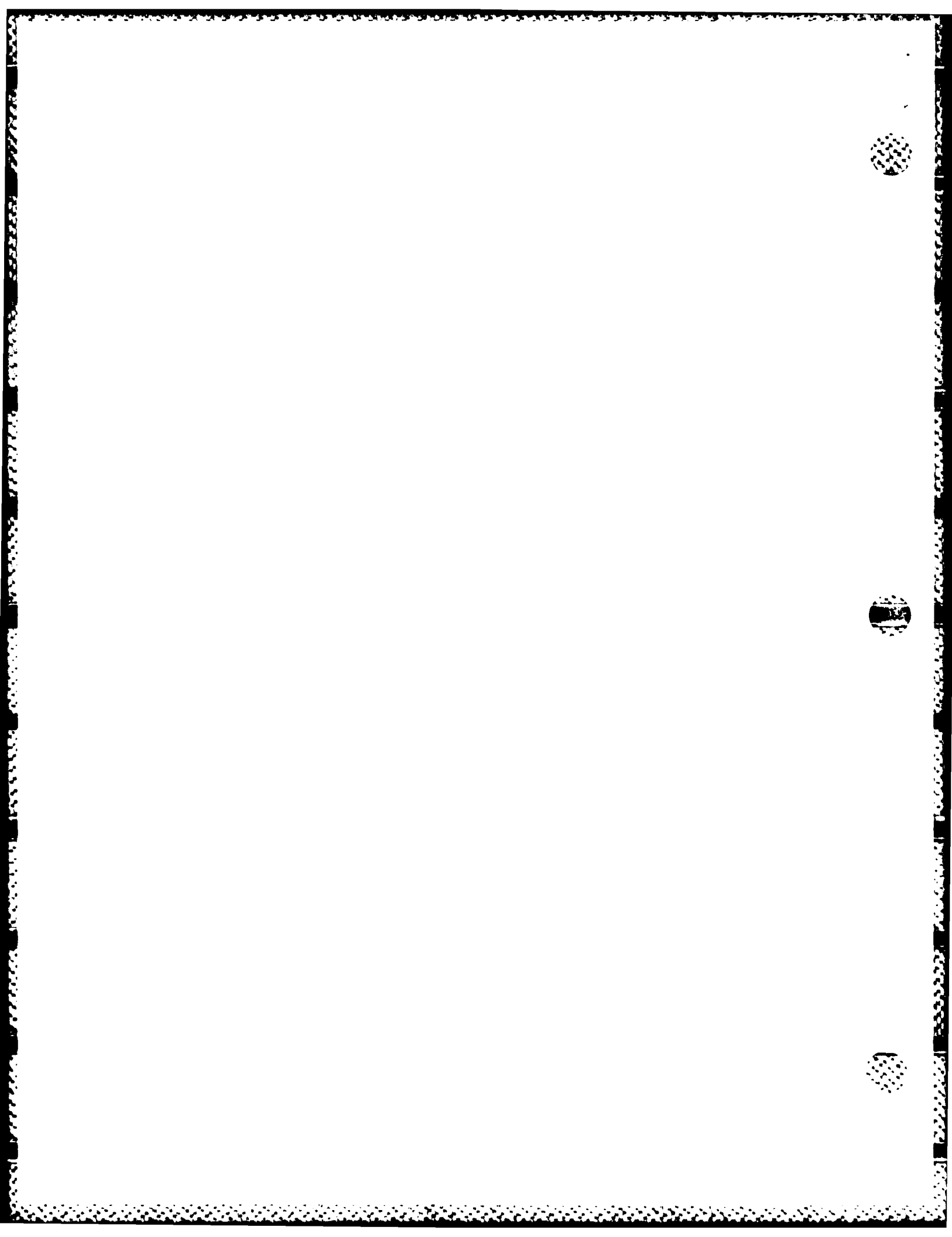
We concluded that the OSV conversion concept has definite merit as an alternative to new construction, and it warrants further study. The converted design could operate as a buoy tender with some restriction on other operations, as previously noted. It is recommended that a continued effort be made to study this concept and that a critical review of this report be performed. The authors welcome any comments which the reviewing authorities might have.

## OSV-BOUY TENDER CONVERSION

DESIGN REQUIREMENTS	THRESHOLD	GOAL	ACTUAL
PAYLOAD			
FUEL	33.5 LT	33.5 LT	58 LT
WATER	56 LT	56 LT	56 LT
CARGO	50 LT	50 LT	50 LT
CRANE LIFT CAPACITY	10 LT	20 LT	20 LT
SPEED	12KT	16 KT	13 KT
RANGE @ 12.5 KTS	1000 NM	4000 NM	4000 NM
ENDURANCE PERIOD	21 DAYS	21 DAYS	21 DAYS
STABILITY			
FLOODABLE LENGTH INTACT	ABS RULES USN STDS	2 COMPARTMENT USN STDS	ABS <sup>1</sup> USN STDS
SEAKEEPING			
CONDUCT BOUY OPS	SEA STATE 3	SEA STATE 4	SEA STATE 4
OUTFIT			
	26 FT BOAT 14 FT BOAT	MOTORSURF BOAT RHIB	RHIB RHIB
DRAFT	14 FT	MINIMUM	9.7 FT
FREEBOARD	5 FT	7 FT	4.0 FT
ICEBREAKING			
RAM	14 IN 2 FT	18 IN 3 FT	MINIMAL N/A
LOW SPEED TURN	200 FT	MINIMUM	OWN LENGTH
DIAMETER			
DECK AREA	1600 FT <sup>2</sup>	1600 FT <sup>2</sup>	1900 FT <sup>2</sup>
HABITABILITY	USN STDS	CG PRACTICE	CG PRACTICE
MANNING	48	48	48
5 OFF, 3 CPO, 40 ENLISTED			
ARMAMENT			
	3-0.50 CAL 1.5 LT AMMO	3-0.50 CAL 1.5 LT AMMO	3-0.50 CAL 1.5 LT AMMO

<sup>1</sup> Design fails to meet one compartment standard only in engine room.

Table 4



## References

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OFFSHORE SUPPLY VESSEL  
TO  
BUOY TENDER  
CONVERSION DESIGN  
APPENDICES

Massachusetts Institute  
of Technology  
March, 1986  
LT Larry Bowling  
LTJG John Kaplan  
LTJG Vince Wilczynski



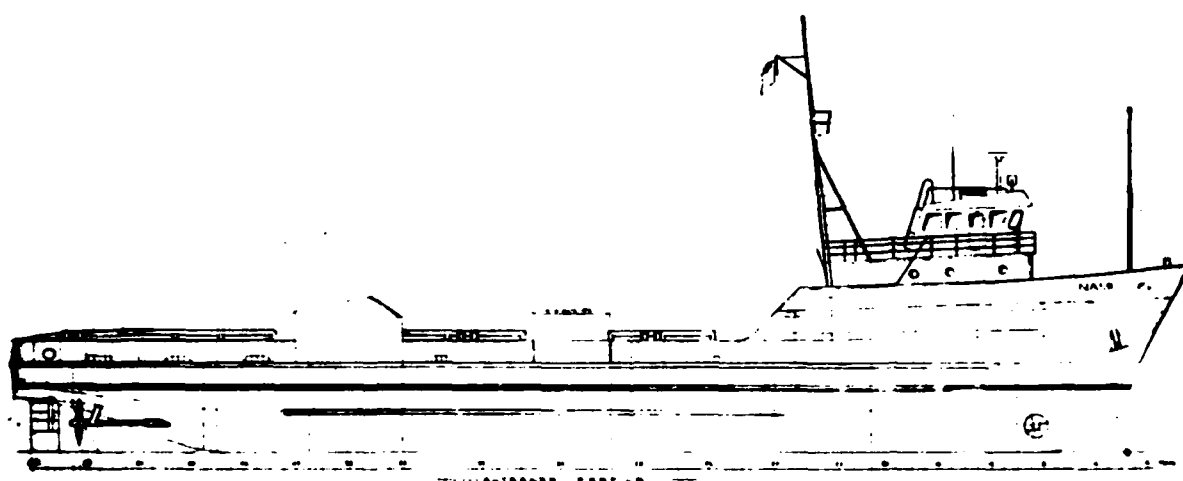
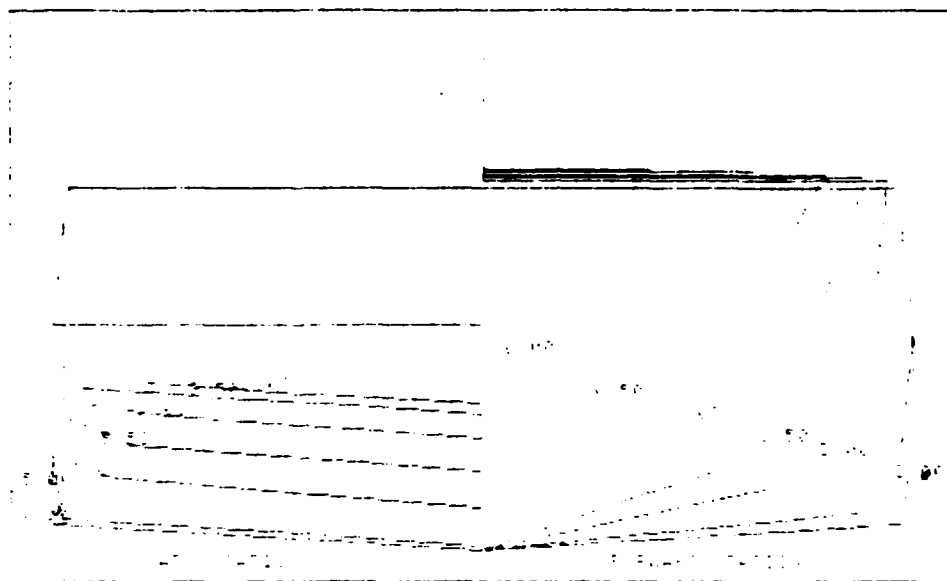
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## APPENDIX 1

### OSV Profile, Offsets, and Lines Drawing

Included in this appendix are a vessel profile drawing, a table of hull offsets, and a lines drawing for a typical OSV.



• Outboard Profile and Hold Plan

\* TYPE OSVOFST.DAT:

Table of Offsets for a Typical OSV

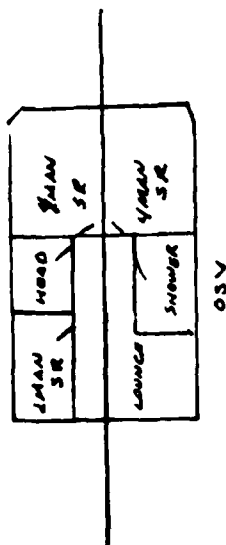
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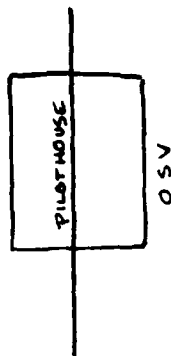
## APPENDIX 2

### General Arrangements

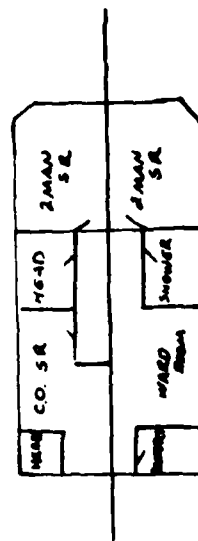
The conversion design's general arrangements are presented beneath the existing typical OSV arrangements to illustrate the required changes. These arrangements show that only minor compartment changes and deckhouse expansion would be required to convert the typical OSV.



OSV

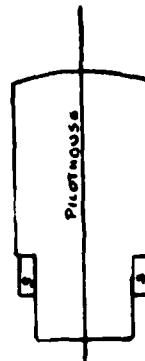


OSV



CONVERSION

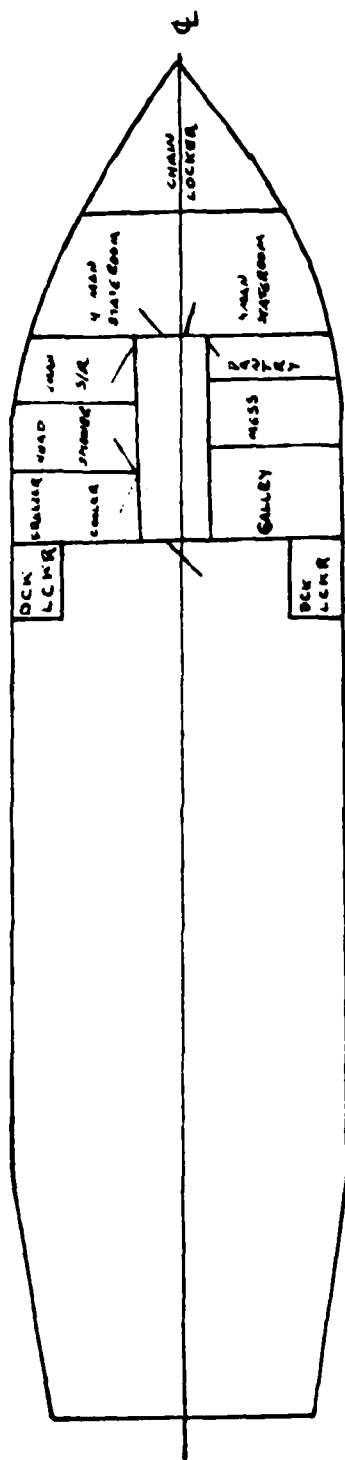
01 DECK



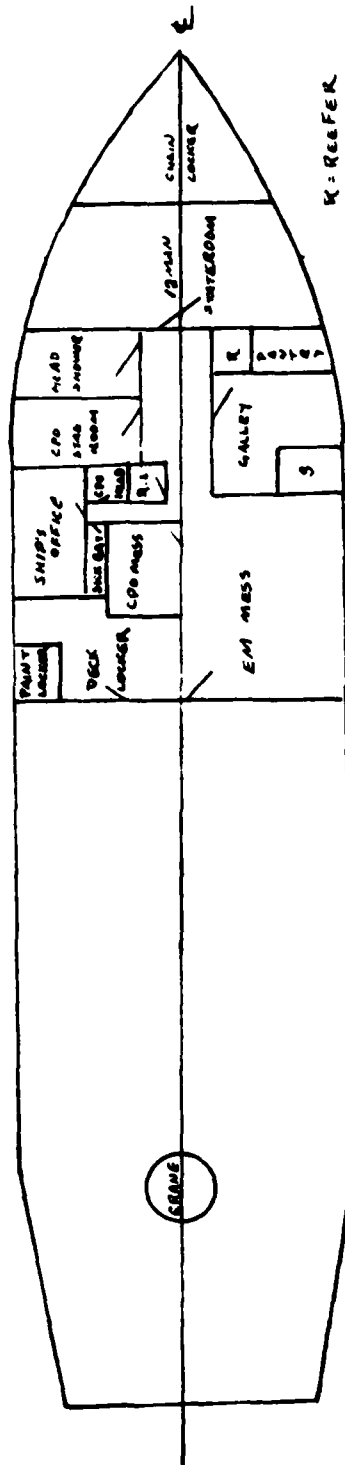
CONVERSION

S = STACK

02 DECK



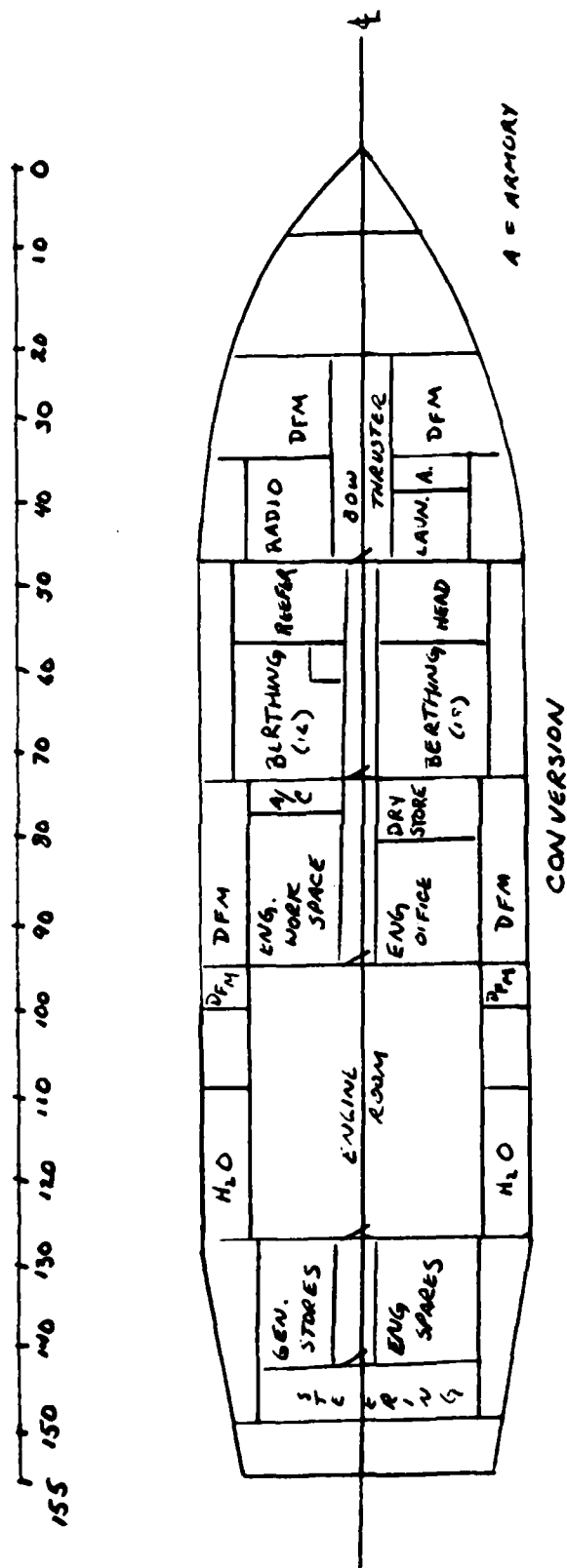
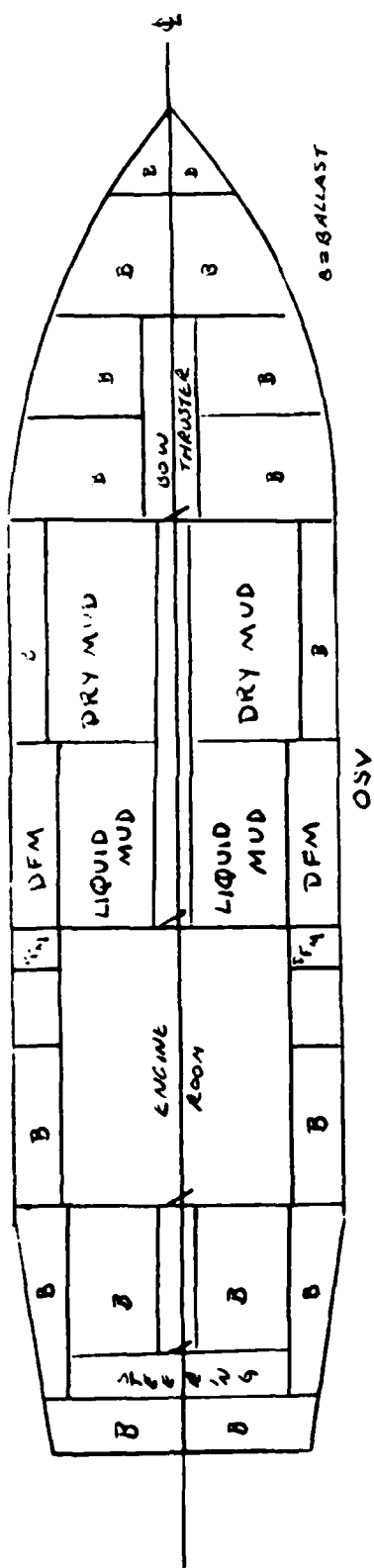
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K = REEFER  
S = SCULLERY  
RL = REPAIR LOCKER

CONVERSION





2 DECK

## APPENDIX 3

### Space Allocation

Contained in this appendix are the space allocation figures used in generating the general arrangement for the converted design. The guideline used in arriving at these values was the U.S. Navy habitability instruction (OPNAV INST 9640.1). Comparisons with similar ship space allocations provided additional target values. These areas are the actual compartment sizes as determined by the final general arrangements plan for the converted design in appendix 2.

SPACE DESCRIPTION	CONVERSION DESIGN (sq. ft.)
Pilothouse	307.50
Central Control	143.75
Ship Office	94.25
General Stores	162.50
Spare Parts	162.50
Bos'n Locker	224.00
Engineering Work Spaces	192.62
C.O. Cabin	188.00
Officers Berthing	297.00
CPOs Berthing	123.25
EM Berthing	787.00
Officer Sanitary Spaces	123.25
CPO Sanitary Spaces	25.00
EM Sanitary Spaces	200.00
Wardroom	166.75
CPO Mess	80.00
EM Mess	497.25
Officer Pantry	40.00
Galley	140.00
Scullery	37.50
Cold Stores	111.375
Dry Food	144.75
Laundry	64.00
A/C Space	55.00
Bow Prop	168.00
Armory	32.00
Sick Bay	2.60
Paint Locker	30.00
Radio Room	96.00

Engine Room	720.00
Repair Locker	30.00
Steering Compartment	126.00

## APPENDIX 4

### Weight Calculations

Weight calculations were based on a typical OSV in the light ship condition as a baseline for displacement. Using the general arrangements as a guide, changes to the existing design were identified as being required additions or removals. An accounting technique recorded the weight, vertical center of gravity, and transverse center of gravity for each item added or removed. The final displacement for the conversion design's full load, lightship, minimum operating, and minimum operating damaged worst case conditions are the sum of these weights and the baseline displacement. Values for KG, LCG, TCG, and trim were determined using:

SM()A = Summation of the vertical, longitudinal,  
or transverse moment added

SM()R = Summation of the moment removed

MTI = Moment to Trim One Inch

D = Displacement

KG = (SMVA - SMVR)/D

LCG = (SMLA - SMLR)/D

TCG = (SMTA - SMTR)/D

TRIM = D \* (LCG - LCB)/MTI

Data is presented for each of the conditions in the following tables.

# FULL LOAD CALCULATIONS

## WEIGHT ADDITIONS

ITEM	WT	VCS	LCG	TCS	NV	ML	MT
DSV LIGHT SHIP	522.90	11.30	81.14	0.00	5908.77	42428.11	0.00
BRIDGE STBD BULKHEAD	0.29	34.00	40.00	-5.50	9.86	11.60	-1.60
BRIDGE PORT BULKHEAD	0.29	34.00	40.00	5.50	9.86	11.60	1.60
BRIDGE AFT BULKHEAD	0.36	34.00	44.00	0.00	12.24	15.84	0.00
STACK STRB	0.66	38.00	38.00	-6.50	25.06	25.06	-4.29
STACK PORT	0.66	38.00	38.00	6.50	25.06	25.06	4.29
DECKHOUSE BULKHEAD	0.40	25.50	50.50	0.00	10.20	20.20	0.00
01 LEVEL AFT BULKHEAD	0.91	25.50	54.00	0.00	26.40	43.20	0.00
CO'S HEAD	0.05	25.50	51.00	7.00	1.29	2.55	0.35
HEAD EQUIPMENT	0.09	24.50	51.00	9.00	2.21	4.55	0.81
PANTRY	0.09	25.50	51.00	-3.00	2.30	4.59	-0.27
PANTRY BULKHEAD	0.18	25.50	49.00	-7.00	4.59	8.02	-1.26
PANTRY EQUIP	0.50	25.50	51.00	-7.00	12.75	25.50	-3.50
RHIB DAVIT	1.80	23.00	69.00	15.50	36.80	103.80	24.80
RHIB	1.20	25.00	60.00	-15.50	36.60	72.00	-18.60
RHIB DAVIT	1.80	23.00	69.00	15.50	36.80	103.80	24.80
RHIB	1.20	25.00	60.00	-15.50	36.60	72.00	-18.60
POWER UNIT	1.00	20.00	50.00	0.00	20.00	0.00	0.00
ENGINE	1.00	17.50	21.00	0.00	3.50	4.00	0.00
PUMP	0.50	17.50	21.00	-12.00	8.75	13.00	-6.00
REEFER	1.00	17.50	25.00	-6.00	10.50	26.00	-5.00
GALLEY	1.00	17.50	40.00	-12.00	10.50	40.00	-12.00
TABLES	0.40	16.00	52.00	-13.00	6.40	20.80	-5.20
BULKHEAD	0.75	17.50	49.00	7.00	13.12	36.00	5.25
REPAIR LOCKER	0.75	17.50	42.00	4.00	13.12	32.25	3.00
CFO HEAD	1.00	17.50	45.00	7.00	1.55	3.57	0.63
SHIP'S OFFICE	1.50	17.50	48.00	15.00	26.25	72.00	22.50
STICK BAY	0.15	17.50	52.00	1.00	1.55	4.25	0.50
CFO LOUNGE	1.00	17.50	55.00	4.00	5.25	16.50	1.20
DECK HOUSE BULKHEAD	1.75	17.50	73.00	0.00	24.15	96.00	0.00
SHELL PLATE	1.50	17.50	59.00	0.00	28.00	94.40	0.00
PAINT LOCKER	0.40	17.50	65.00	15.00	7.00	26.00	6.00
PAINT & EPOXY	0.50	17.50	65.00	15.00	9.75	32.50	7.50
DECK LOCKER	1.50	17.50	60.00	10.00	26.25	90.00	15.00
WTC	1.00	0.00	48.00	0.00	0.00	0.00	0.00
-B	6.00	7.00	7.00	0.00	42.00	42.00	0.00
1-B	50.00	6.50	10.00	0.00	339.00	634.00	0.00
2-B	45.00	6.50	42.00	0.00	35.00	18.00	0.00
24-1-F DFM	26.00	9.50	32.00	-9.00	312.00	1177.00	-370.00
24-2-F DFM	26.00	9.50	32.00	9.00	312.00	1177.00	370.00
74-1-F DFM	41.25	7.00	95.00	-16.00	288.75	3506.25	-60.00
74-2-F DFM	41.25	7.00	95.00	16.00	288.75	3506.25	60.00
117-1-W	26.00	8.50	118.00	-15.00	220.00	3065.00	-395.50
117-2-W	26.00	8.50	118.00	15.00	220.00	3065.00	395.50
114-1-W	5.50	4.00	118.00	-2.00	22.00	649.00	-12.38
114-2-W	5.50	4.00	118.00	2.00	22.00	649.00	12.38
157-B	1.00	11.00	153.00	0.00	0.00	0.00	0.00
DAY TANK	24.75	7.00	99.00	0.00	172.32	2451.24	0.00
LUBE OIL	7.00	7.00	104.00	0.00	21.30	735.40	0.00
ARPCO	2.00	7.00	38.00	-8.00	14.00	76.00	-16.00
LAUNDRY	0.32	7.00	44.00	-8.00	2.31	14.52	-2.64
RADIO EQUIP	3.00	7.00	42.00	8.00	21.00	126.00	24.00
REEFER/CHILL	1.40	7.00	52.00	9.00	9.80	72.80	12.60

PROVISIONS	1.60	7.00	53.00	9.00	11.20	84.80	14.40
REEFER MACHINERY	0.65	4.00	58.00	4.00	2.60	37.70	2.60
12 MAN BERTHING	0.85	7.00	68.00	9.50	5.60	54.40	7.50
HEAD	1.20	7.00	65.00	-8.50	8.40	78.00	-14.20
A/C SPACE	6.70	7.00	76.00	7.50	46.90	509.20	50.25
ENGINEERING WORK ROOM	5.00	7.00	88.00	7.50	35.00	440.00	37.50
DRY STORES	1.90	7.00	78.00	-7.50	13.30	148.20	-14.25
ENGINEERING OFFICE	1.00	7.00	88.00	-7.53	7.00	86.00	-7.53
EVAPORATOR	8.00	5.00	104.00	0.00	40.00	832.00	0.00
GENERAL MODIFICATIONS	0.60	7.00	120.00	0.00	4.20	72.00	0.00
SPARE PARTS	6.70	9.00	138.00	-7.00	60.30	924.60	-46.90
GENEAL STORES	5.00	9.00	138.00	7.00	45.00	690.00	35.00
OFFICERS COUNTRY	0.90	25.00	35.00	0.00	22.50	31.50	0.00
FORWARD CREW BERTHING	1.20	17.00	17.00	0.00	20.40	20.40	0.00

CPD BERTHING		0.40	17.00	36.00	11.00	6.80	14.40	4.40
BTBD CREW BERTHING	1.60	7.00	65.00	-8.00	12.60	117.00	-14.40	
PORT CREW BERTHING	1.20	7.00	65.00	8.00	8.40	78.00	9.60	
CRANE	40.00	76.50	125.00	0.00	1460.00	5900.00	0.00	
DECK CARGO	50.00	18.50	75.00	0.00	925.00	480.00	0.00	
CRANE SUPPORT	10.00	5.00	125.00	0.00	80.00	1250.00	0.00	

TOTALS	1051.5			11977.82	62030.26	164.54
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WEIGHT REMOVALS							
A/C	0.50	31.00	39.00	0.00	15.50	19.00	0.00
BRIDGE BULKHEAD	0.50	74.00	39.00	0.00	17.34	18.34	0.00
DECK HOUSE BUL HEAD	0.50	25.50	49.00	0.00	20.40	38.40	0.00
DECK STATEROOM	0.65	25.50	44.00	4.00	1.20	2.20	0.00
SMALL BOAT	0.04	20.00	50.00	9.00	0.90	0.20	0.00
BULKHEAD	0.10	17.50	17.00	0.00	1.75	1.70	0.00
HEAD	0.15	17.00	74.00	18.00	2.55	5.10	1.50
PANTRY	0.50	17.50	26.00	-8.00	5.75	13.00	-4.00
MESS TABLE	0.20	16.00	34.00	-10.00	3.20	6.80	-2.40
GALLEY	1.00	17.50	43.00	12.00	17.50	40.00	10.00
FREETER	2.00	17.50	44.00	10.00	35.00	36.00	24.00
BULKHEAD	1.75	17.50	49.00	0.00	24.15	66.24	0.00
DECK LOCKER	0.50	17.50	50.00	0.00	10.50	31.00	0.00
DECK LOCKER	1.00	17.50	50.00	0.00	17.50	50.00	0.00
NON WTB	0.04	6.00	49.00	0.00	1.04	1.92	0.00
WLD TANKS	5.00	9.00	55.00	0.00	40.00	275.00	0.00
WLD TANKS	5.00	9.00	55.00	0.00	40.00	240.00	0.00
WLD PUMP	1.50	5.00	109.00	0.00	7.50	140.00	0.00

SUP	20.37			264.04	1166.20	31.66
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DISP FULL LOAD	1031.10
KG FULL LOAD	11.20
LCB FT AFT OF FP	76.42
TCB FT +PORT	0.10
MT:	122.70
LCB FT AFT OF FP	78.00
TRIM IN +BY STERN	3.55
DRAFT FT	9.70

# LIGHT SHIP CALCULATIONS

## WEIGHT ADDITIONS

ITEM	WT	VCG	LCG	TCS	MV	ML	MT
OSV LIGHT SHIP	522.90	11.30	81.14	0.00	5906.77	42428.11	0.00
BRIDGE STBD BULKHEAD	0.29	34.00	40.00	-5.50	9.56	11.60	-1.60
BRIDGE PORT BULKHEAD	0.29	34.00	40.00	5.50	9.56	11.60	1.60
BRIDGE AFT BULKHEAD	0.36	34.00	44.00	0.00	12.24	15.84	0.00
STACK STBD	0.66	38.00	38.00	-6.50	22.62	25.08	-4.25
STACK PORT	0.66	38.00	38.00	6.50	22.62	25.08	4.25
DECKHOUSE BULKHEAD	0.40	25.50	50.50	0.00	10.20	20.20	0.00
01 LEVEL AFT BULKHEAD	0.80	25.50	54.00	0.00	20.40	41.20	0.00
CO S HEAD	0.05	25.50	51.00	0.00	1.25	2.55	0.35
HEAD EQUIPMENT	0.09	24.50	51.00	0.00	2.21	4.59	0.81
PANTRY	0.09	25.50	51.00	-3.00	2.30	4.59	-0.27
PANTRY BULKHEAD	0.18	25.50	49.00	-7.00	4.59	6.62	-1.26
PANTRY BULKHEAD	0.50	25.50	51.00	-7.00	12.25	25.50	-3.50
MSE CH	1.60	20.00	69.00	15.00	36.80	106.80	24.80
MSE	1.20	25.00	60.00	-15.00	30.00	70.00	-10.00
PANTRY CH	1.50	20.00	69.00	15.00	36.80	106.80	24.80
CH	1.20	25.00	60.00	-15.00	30.00	70.00	-10.00
POWDER	1.20	20.00	60.00	15.00	30.00	60.00	0.00
POWDER	1.20	20.00	60.00	-15.00	30.00	60.00	-0.00
PAINT	0.50	17.50	26.00	-10.00	8.75	17.50	-5.00
REEFER	1.40	17.50	26.00	-10.00	24.50	26.00	-6.00
GALLERY	1.00	17.50	40.00	-10.00	17.50	40.00	-10.00
TABLES	1.40	16.00	50.00	-10.00	22.40	20.80	-5.20
BULKHEAD	0.75	17.50	48.00	0.00	13.12	36.00	5.25
REPAIR LOCKER	0.75	17.50	47.00	0.00	13.12	32.25	0.00
CO S HEAD	0.05	17.50	47.00	0.00	0.88	10.67	0.67
SH-100 LOCKER	1.50	17.50	48.00	15.00	26.25	70.00	21.50
SH-100	0.05	17.50	50.00	0.00	0.88	4.00	0.00
CO S LOCKER	0.75	17.50	55.00	0.00	13.12	16.50	1.00
DECKHOUSE BULKHEAD	1.35	17.50	70.00	0.00	24.15	96.60	0.00
SHELL PLATE	1.60	17.50	55.00	0.00	28.00	94.40	0.00
PANTRY LOCKER	1.40	17.50	55.00	15.00	24.50	26.00	6.00
PANTRY LOCKER	1.50	17.50	65.00	15.00	30.75	30.50	7.50
CO S LOCKER	1.50	17.50	60.00	0.00	24.50	60.00	15.00
WT	0.10	6.00	48.00	0.00	0.60	6.00	0.00
WT	0.05	7.00	30.00	0.00	0.35	0.00	0.00
WT	0.05	6.00	30.00	0.00	0.35	0.00	0.00
WT	0.05	6.00	40.00	0.00	0.35	0.00	0.00
24-100 DPH	0.00	6.50	32.00	-5.00	0.00	0.00	0.00
24-100 DPH	0.00	6.50	32.00	5.00	0.00	0.00	0.00
24-100 DPH	0.00	7.00	85.00	15.00	0.00	0.00	0.00
24-100 DPH	0.00	7.00	65.00	15.00	0.00	0.00	0.00
110 DPH	0.00	8.50	118.00	-15.00	0.00	0.00	0.00
110 DPH	0.00	8.50	118.00	15.00	0.00	0.00	0.00
110 DPH	0.00	4.00	118.00	-2.25	0.00	0.00	0.00
110 DPH	0.00	4.00	118.00	2.25	0.00	0.00	0.00
150 DPH	0.00	11.00	150.00	0.00	0.00	0.00	0.00
24-100 DPH	0.00	7.00	95.00	0.00	0.00	0.00	0.00
CO S LOCKER	0.00	0.00	104.00	0.00	0.00	0.00	0.00
ARMORY	2.00	7.00	38.00	-8.00	14.00	76.00	-16.00
LAUNDRY	0.33	7.00	44.00	-8.00	2.31	14.52	-2.64
RADIO EQUIP	3.00	7.00	42.00	8.00	21.00	126.00	24.00
REEFER CHILL	1.40	7.00	52.00	9.00	9.80	72.80	12.60

PROVISIONS	0.00	7.00	53.00	9.00	0.00	0.00	0.00
REEFER MACHINERY	0.65	4.00	58.00	4.00	2.60	37.70	2.60
12 MAN BERTHING	0.80	7.00	68.00	9.50	5.60	54.40	7.60
HEAD	1.20	7.00	65.00	-8.50	8.40	78.00	-10.20
A/C SPACE	6.70	7.00	76.00	7.50	46.90	509.20	50.25
ENGINEERING WORK ROOM	5.00	7.00	86.00	7.50	35.00	440.00	37.50
DRY STORES	0.00	7.00	79.00	-7.50	0.00	0.00	0.00
ENGINEERING OFFICE	1.00	7.00	95.00	-7.50	7.00	88.00	-7.50
EVAFFWATER	8.00	5.00	104.00	0.00	40.00	372.00	0.00
GENERAL MODIFICATIONS	0.60	7.00	126.00	0.00	4.20	72.00	0.00
SPARE PARTS	0.00	9.00	138.00	-7.00	0.00	0.00	0.00
GENERAL STORES	0.00	9.00	179.00	7.00	0.00	0.00	0.00
OFFICERS COUNTRY	0.90	25.00	35.00	0.00	22.50	31.50	0.00
FORWARD CREW BERTHING	1.20	17.00	17.00	0.00	20.40	20.40	0.00
CFO BERTHING	0.40	17.00	36.00	11.00	6.80	14.40	4.40
STBD CREW BERTHING	1.80	7.00	65.00	-8.00	12.60	117.00	-14.40
PORT CREW BERTHING	1.20	7.00	65.00	8.00	8.40	78.00	9.60
CRANE	40.00	25.50	125.00	0.00	148.00	509.00	0.00
DECK CRANE	0.00	18.00	96.00	0.00	0.00	0.00	0.00
CRANE LIFTING	10.00	8.00	125.00	0.00	80.00	125.00	0.00

TOTAL ADDITIONS	670.74				8201.80	52575.02	176.09
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WEIGHT BONDABLE							
A/C	0.50	11.00	38.00	0.00	15.50	19.00	0.00
BRIDGE BULKHEAD	0.50	14.00	35.00	0.00	17.24	15.36	0.00
DECK HOUSE BULKHEAD	0.20	25.50	45.00	0.00	20.40	38.40	0.00
COLE'S STATEROOM	0.00	25.50	44.00	4.00	1.26	2.20	0.20
SMALL BOAT	0.04	10.00	57.00	0.00	0.88	0.28	0.24
BULKHEAD	0.10	17.50	17.00	0.00	1.75	1.70	0.00
HEAD	0.15	17.00	74.00	0.00	0.55	5.00	0.50
REAR	0.05	17.50	26.00	-8.00	8.70	10.70	-4.00
MIDSE TRALE	0.20	16.00	74.00	-12.00	0.20	6.80	-12.40
GALE+	0.00	17.50	47.00	10.00	17.50	47.00	12.00
FRONTIER	0.00	17.50	47.00	10.00	15.00	38.00	14.00
SUNHEAD	0.00	17.50	45.00	0.00	24.15	16.04	0.00
DECK LADDER	0.00	17.50	50.00	0.00	10.00	10.00	0.00
DECK LADDER	0.00	17.50	50.00	0.00	10.00	50.00	0.00
WALL	0.04	0.00	45.00	0.00	0.04	0.00	0.00
MID TANK	0.00	0.00	55.00	0.00	4.00	0.00	0.00
MID TANK	0.00	0.00	60.00	0.00	4.00	0.00	0.00
MID TANK	0.00	0.00	60.00	0.00	4.00	0.00	0.00
MID TANK	0.00	0.00	60.00	0.00	4.00	0.00	0.00

SUM	20.77				264.04	1116.20	31.66
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DISPLACEMENT LIGHT SHIP	611.97
K6 LIGHT SHIP	17.01
LCR	84.01
TOR	0.24
MTI*	78.50
LCR	78.10
TRIM INCHES + STERN	50.53
DRAFT FT	6.60



# MINIMUM OPERATING CONDITION

## WEIGHT ADDITIONS

ITEM	WT	VC6	LC6	TC6	MV	ML	M7
OSV LIGHT SHIP	522.90	11.30	81.14	0.00	5908.77	42428.11	0.00
BRIDGE STBD BULKHEAD	0.29	34.00	40.00	-5.50	9.86	11.60	-1.60
BRIDGE PORT BULKHEAD	0.29	34.00	40.00	5.50	9.86	11.60	1.60
BRIDGE AFT BULKHEAD	0.36	34.00	44.00	0.00	12.24	15.84	0.00
STADI STRE	0.66	38.00	38.00	-6.50	25.06	25.06	-4.29
STADI PORT	0.66	38.00	38.00	6.50	25.06	25.06	4.29
DECKHOUSE BULKHEAD	0.40	25.50	50.50	0.00	10.20	20.20	0.00
01 LEVEL AFT BULKHEAD	0.80	25.50	54.00	0.00	20.40	43.20	0.00
00'S HEAD	0.05	25.50	51.00	7.00	1.28	2.55	0.35
HEAD EQUIPMENT	0.09	24.50	51.00	9.00	2.21	4.59	0.81
PANTRY	0.09	25.50	51.00	-3.00	2.30	4.59	-0.27
PANTRY BULKHEAD	0.16	25.50	49.00	-7.00	4.59	8.82	-1.26
PANTRY EQUIP	0.50	25.50	51.00	-7.00	12.75	25.50	-3.50
RACE DAVIT	1.60	23.00	69.00	15.50	36.87	106.97	24.80
RACE	1.20	25.00	67.00	-15.50	34.00	72.00	-19.60
RACE DAVIT	1.60	23.00	69.00	15.50	36.87	106.97	24.80
RACE	1.20	25.00	67.00	15.50	34.00	72.00	18.60
POWER DAVIT	1.20	23.00	50.00	0.00	27.97	60.00	0.00
ENGINE	1.20	17.50	21.00	4.00	3.50	4.20	0.00
WATER	1.50	17.50	24.00	-12.00	9.75	12.00	-6.00
REEFER	1.00	17.50	25.00	-6.00	17.50	25.00	-6.00
SAILER	1.00	17.50	40.00	-12.00	17.50	40.00	-12.00
TABLES	0.40	16.00	52.00	-12.00	6.40	20.80	-5.20
STOVEHEAD	0.75	17.50	45.00	7.00	13.13	34.00	5.25
REFRIG COOLER	0.75	17.50	42.00	4.00	13.13	32.25	3.00
ICE HEAD	1.00	17.50	42.00	7.00	1.56	2.87	0.67
ENGINE COOLER	1.50	17.50	45.00	15.00	25.25	70.00	22.50
ENGINE	1.00	17.50	52.00	10.00	1.56	4.66	0.00
ICE COOLER	0.75	17.50	55.00	4.00	5.25	16.50	1.20
DECK HOUSE BULKHEAD	1.38	17.50	70.00	0.00	24.15	94.60	0.00
SHELL PLATE	1.60	17.50	59.00	0.00	38.07	94.40	0.00
PAINT COLE	0.40	17.50	65.00	15.00	7.00	24.00	6.00
PAINT & BELT	0.50	17.50	65.00	15.00	8.75	32.50	7.50
ICE COOLER	1.50	17.50	60.00	10.00	24.25	90.00	15.00
ICE	0.17	6.00	48.00	0.00	0.75	6.24	0.00
ICE	6.00	7.00	7.00	0.00	42.00	42.00	0.00
ICE	50.00	6.50	17.00	0.00	375.00	394.00	0.00
ICE	45.00	6.50	42.00	0.00	252.50	189.00	0.00
74-14F DFH	12.27	8.50	32.00	-9.00	104.70	350.64	-110.47
74-14F DFH	12.27	8.50	32.00	9.00	104.70	350.64	110.47
74-14F DFH	12.75	7.00	85.00	-16.00	96.25	1168.75	-220.00
74-14F DFH	12.75	7.00	85.00	16.00	96.25	1168.75	220.00
112-14A	8.67	8.50	115.00	-15.25	73.70	1013.86	-132.22
112-14A	8.67	8.50	118.00	15.25	73.70	1027.94	132.22
114-14A	1.80	4.00	118.00	-2.25	7.32	215.94	-4.12
114-14A	1.80	4.00	118.00	2.25	7.32	215.94	4.12
150-B	0.00	11.00	153.00	0.00			
150-14A	8.25	7.00	99.00	0.00	57.75	916.75	0.00
150-14A	2.37	3.00	104.50	0.00	7.11	246.40	0.00
ARMORY	2.00	7.00	38.00	-8.00	14.00	76.00	-16.00
LAUNDRY	0.33	7.00	44.00	-8.00	2.31	14.52	-2.64
RADIO EQUIP	3.00	7.00	42.00	8.00	21.00	126.00	24.00
REEFER/CHILL	1.40	7.00	52.00	9.00	9.80	72.80	12.60

PROVISIONS	0.53	7.00	53.00	9.00	3.71	28.09	4.77
REEFER MACHINERY	0.65	4.00	58.00	4.00	2.60	37.70	2.60
12 MAN BERTHING	0.80	7.00	68.00	9.50	5.60	54.40	7.60
HEAD	1.20	7.00	65.00	-8.50	8.40	78.00	-10.20
A/C SPACE	6.70	7.00	76.00	7.50	46.90	509.20	50.25
ENGINEERING WORK ROOM	5.00	7.00	88.00	7.50	35.00	440.00	37.50
DRY STORES	0.63	7.00	78.00	-7.50	4.41	49.14	-4.73
ENGINEERING OFFICE	1.00	7.00	88.00	-7.50	7.00	88.00	-7.50
EVAPORATOR	8.00	5.00	104.00	0.00	40.00	872.00	0.00
GENERAL MODIFICATIONS	0.60	7.00	120.00	0.00	4.20	72.00	0.00
SPARE PARTS	2.23	9.00	138.00	-7.00	20.07	307.74	-15.61
GENERAL STORES	1.67	9.00	138.00	7.00	15.03	230.46	11.69
OFFICERS COUNTRY	0.90	25.00	35.00	0.00	22.50	31.50	0.00
FORWARD CREW BERTHING	1.20	17.00	17.00	0.00	20.40	21.40	0.00
CPO BERTHING	0.40	17.00	36.00	11.00	6.80	14.40	4.40
STBC CREW BERTHING	1.80	7.00	65.00	-8.00	12.60	117.00	-14.40
PORT CREW BERTHING	1.20	7.00	65.00	8.00	8.40	78.00	9.60
CRANE	47.00	26.50	128.00	0.00	1460.00	5000.00	0.00
DECK CASE	5.00	15.00	55.00	0.00	925.00	4800.00	0.00
CRANE SUPPORT	10.00	8.00	128.00	0.00	80.00	1280.00	0.00
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TOTALS	374.13			10491.50	67470.75	172.42	

# WEIGHT REMOVALS

A/C	0.50	24.00	38.00	0.00	15.50	19.00	0.00
BRIDGE BULKHEAD	0.50	24.00	38.00	0.00	17.34	18.39	0.00
COCK HOUSE BULKHEAD	0.6	25.50	48.00	0.00	20.40	38.40	0.00
CO'S STATEROOM	1.05	25.50	44.00	4.00	1.28	0.20	0.20
SMALL BOAT	1.04	22.00	57.00	9.00	0.80	0.25	0.25
BULKHEAD	0.10	17.50	17.00	0.00	1.75	1.75	0.00
HEAD	0.15	17.00	24.00	10.00	2.55	5.10	1.50
PANTRY	0.50	17.50	28.00	-8.00	8.75	17.00	-4.00
MESS TABLE	0.20	16.00	24.00	-12.00	3.20	6.80	-2.40
GALLEY	1.00	17.50	42.00	12.00	17.50	42.00	12.00
FREEZER	0.00	17.50	44.00	12.00	35.00	55.00	24.00
BULKHEAD	1.75	17.5	48.00	0.00	24.15	66.24	0.00
DECK LOCKER	1.0	17.50	52.00	0.00	10.50	21.00	0.00
DECK LOCKER	1.00	17.5	52.00	0.00	10.50	52.00	0.00
MIN. A/C	0.04	6.00	45.00	0.00	0.24	1.92	0.00
MUD TANK	5.0	8.00	55.00	0.00	40.00	275.00	0.00
MUD TANK	5.00	8.00	55.00	0.00	40.00	240.00	0.00
MUD PUMP	1.50	5.00	105.00	0.00	7.50	150.00	0.00

SUM	29.77			264.04	1168.20	31.66	
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DISP MINIMUM OPERATING	850.65
VS MIN OF	11.98
LCB FT AFT OF FP	77.67
TGB FT +PORT	9.16
MT1*	98.00
LCB FT AFT OF FP	77.34
TRIM IN +8% STEPS	3.01
DRAFT FT	8.50

# MINIMUM OPERATING DAMAGED CONDITION WORST CASE

WEIGHT ADDITIONS	ITEM	WT	VC6	LC6	TC6	MV	ML	MT
	OSV LIGHT SHIP	522.90	11.30	81.14	0.00	5909.77	42428.11	0.00
	BRIDGE STBD BULKHEAD	0.29	34.00	40.00	-5.50	9.86	11.60	-1.60
	BRIDGE PORT BULKHEAD	0.29	34.00	40.00	5.50	9.86	11.60	1.60
	BRIDGE AFT BULKHEAD	0.36	34.00	44.00	0.00	12.24	15.94	0.00
	STACK STEB	0.66	38.00	38.00	-6.50	25.08	25.08	-4.29
	STACK PORT	0.66	38.00	38.00	6.50	25.08	25.08	4.29
	DECKHOUSE BULKHEAD	0.40	25.50	50.50	0.00	10.20	20.20	0.00
	01 LEVEL AFT BULKHEAD	0.80	25.50	54.00	0.00	20.40	47.20	0.00
	CO S HEAD	0.05	25.50	51.00	7.00	1.28	2.55	0.35
	HEAD EQUIPMENT	0.09	24.50	51.00	9.00	2.21	4.59	0.81
	PANTRY	0.05	25.50	51.00	-3.00	2.31	4.59	-0.27
	PANTRY BULKHEAD	0.18	25.50	49.00	-7.00	4.59	8.82	-1.26
	PANTRY EQUIP	0.50	25.50	51.00	-7.00	12.75	25.50	-3.50
	RHIB DAVIT	1.68	25.00	68.00	15.50	35.80	106.80	24.80
	RHIB	1.20	25.00	60.00	-15.50	30.00	72.00	-18.60
	RHIB DAVIT	1.68	25.00	68.00	15.50	35.80	106.80	24.80
	RHIB	1.20	25.00	60.00	-15.50	30.00	72.00	-18.60
	POWER UNIT	1.00	27.00	51.00	0.00	20.60	60.00	0.00
	BUNK	0.00	17.50	21.00	0.00	3.50	4.20	0.00
	PANTRY	0.50	17.50	26.00	-12.00	9.75	13.00	-6.75
	REEFER	1.00	17.50	26.00	-6.00	17.50	26.00	-6.00
	GALLEY	1.00	17.50	40.00	-12.00	17.50	40.00	-12.00
	TABLES	0.40	17.50	50.00	-10.00	6.40	29.80	-5.20
	BULKHEAD	0.75	17.50	48.00	7.00	10.00	36.00	5.25
	REPAIR LOCKER	0.75	17.50	40.00	4.00	13.00	32.25	3.00
	OPS HEAD	0.09	17.50	40.00	7.00	1.90	3.80	0.63
	SHIP'S OFFICE	1.50	17.50	48.00	15.00	26.25	72.00	22.50
	ENG BR	0.09	17.50	52.00	10.00	1.50	4.50	0.90
	ENG LOUNGE	0.70	17.50	55.00	4.00	5.25	16.50	1.20
	DECK HOUSE BULKHEAD	1.38	17.50	70.00	0.00	24.00	96.00	0.00
	SHELL PLATE	1.60	17.50	59.00	0.00	28.00	94.40	0.00
	PAINT LOCKER	0.40	17.50	65.00	15.00	7.00	26.00	6.00
	PAINT & EQUIP	0.50	17.50	65.00	15.00	8.75	32.50	7.50
	DECK LOCKER	1.50	17.50	60.00	10.00	11.25	56.00	15.00
	ATC	0.10	6.60	43.00	0.00	0.75	6.24	0.00
	1-E	6.00	7.00	7.00	0.00	42.00	42.00	0.00
	2-E	52.00	6.50	17.00	0.00	328.00	864.00	0.00
	3-E	45.00	6.50	40.00	0.00	292.50	1650.00	0.00
	24-1-F DFM	12.00	8.50	32.00	-9.00	164.70	392.64	-110.40
	24-2-F DFM	12.00	8.50	32.00	9.00	164.70	392.64	110.40
	74-1-F DFM	13.75	7.00	85.00	-16.00	98.25	1168.75	-220.00
	74-2-F DFM	13.75	7.00	85.00	16.00	98.25	1168.75	220.00
	112-1-N	8.67	6.50	118.00	-15.25	72.70	1023.06	-132.22
	112-2-N	8.67	6.50	118.00	15.25	72.70	1023.06	132.22
	114-1-N	1.93	4.00	118.00	-2.25	7.00	215.94	-4.12
	114-2-N	1.93	4.00	118.00	2.25	7.00	215.94	4.12
	150-B	0.00	11.00	153.00	0.00			
	24-TANKS	8.25	7.00	95.00	0.00	57.75	916.75	0.00
	LOSE OIL	2.00	7.00	104.00	0.00	7.00	248.40	0.00
	ARMORY	2.00	7.00	38.00	-8.00	14.00	76.00	-16.00
	LAUNDRY	0.70	7.00	44.00	-8.00	2.31	14.52	-2.64
	RADIO EQUIP	3.00	7.00	42.00	8.00	21.00	126.00	24.00
	REEFER/CHILL	1.40	7.00	52.00	9.00	9.80	72.80	12.60

PROVISIONS	0.53	7.00	53.00	9.00	3.71	28.09	4.77
REEFER MACHINERY	0.65	4.00	58.00	4.00	2.60	37.70	2.60
12 MAN BERTHING	0.80	7.00	68.00	9.50	5.60	54.40	7.60
HEAD	1.20	7.00	65.00	-8.50	8.40	78.00	-10.20
A/C SPACE	6.70	7.00	76.00	7.50	46.90	509.20	50.25
ENGINEERING WORK ROOM	5.00	7.00	88.00	7.50	35.00	440.00	37.50
DRY STORES	0.63	7.00	78.00	-7.50	4.41	49.14	-4.73
ENGINEERING OFFICE	1.00	7.00	88.00	-7.53	7.00	88.00	-7.53
EVAPORATOR	8.00	5.00	104.00	0.00	40.00	832.00	0.00
GENERAL MODIFICATIONS	0.60	7.00	120.00	0.00	4.20	72.00	0.00
SPARE PARTS	2.25	9.00	138.00	-7.00	20.07	307.74	-15.61
GENERAL STORES	1.67	9.00	138.00	7.00	15.03	230.46	11.69
OFFICERS COUNTRY	0.90	25.00	35.00	0.00	22.50	31.50	0.00
FORWARD CREW BERTHING	1.20	17.00	17.00	0.00	20.40	20.40	0.00
CPC BERTHING	0.40	17.00	36.00	11.00	6.80	14.40	4.40
STEEL CREW BERTHING	1.80	7.00	65.00	-8.00	12.60	117.00	-14.40
PORT CREW BERTHING	1.20	7.00	65.00	8.00	8.40	78.00	9.60
CRANE	40.00	36.50	125.00	0.00	1460.00	5000.00	0.00
DECK CRANE	50.00	19.50	95.00	0.00	925.00	490.00	0.00
CRANE SUPPORT	10.00	6.00	125.00	0.00	80.00	1250.00	0.00
DAMAGED FLOODING	260.20	8.50	118.00	0.00	174.40	30415.20	0.00

TOTALS	1134.26			12195.80	97883.96	171.42
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# WEIGHT REMOVALS

A/C	0.50	11.00	38.00	0.00	15.50	19.00	0.00
BRIDGE BULKHEAD	0.51	24.00	36.00	0.00	17.04	15.36	0.00
DECK HOUSE BULKHEAD	1.81	25.50	48.00	0.00	20.40	35.40	0.00
CO'S STATEROOM	1.00	25.50	44.00	4.00	1.20	2.20	0.00
SMALL BOAT	0.04	22.00	57.00	9.00	0.86	2.22	0.36
BULKHEAD	0.10	17.50	17.00	0.00	1.75	1.70	0.00
HEAT	0.15	17.00	34.00	10.00	0.55	5.10	1.50
PANTRY	0.50	17.50	26.00	-8.00	8.75	17.00	-4.00
MESS TABLE	0.20	16.00	34.00	-12.00	0.20	6.80	-2.40
GALLEY	1.00	17.50	40.00	10.00	17.50	40.00	10.00
FREEDER	2.00	17.50	44.00	10.00	35.00	85.00	24.00
BULKHEAD	1.00	17.50	45.00	0.00	24.00	56.24	0.00
DECK LOCKER	0.50	17.50	50.00	0.00	10.50	21.00	0.00
DECK LOCKER	1.00	17.50	50.00	0.00	17.50	51.00	0.00
MUN. WT.	0.04	5.00	48.00	0.00	0.24	1.92	0.00
MUD TANKS	5.00	8.00	55.00	0.00	40.00	275.00	0.00
MUD TANKS	5.00	8.00	65.00	0.00	40.00	340.00	0.00
MUD PUMP	1.50	5.00	108.00	0.00	7.50	160.00	0.00

SUM	28.37			264.04	1166.20	31.66
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DISP MIN OF DAMAGED	1115.89
KG MIN OF	10.59
LCB FT AFT OF FP	65.67
TCE FT +PORT	0.10
M11	130.00
LCE FT AFT OF FP	78.95
TRIM IN +BY STERN	67.17
DRAFT FT	10.30

## APPENDIX 5

### Structural Calculations

Structural changes for the conversion design are:

1. structural support for concentrated loads on deck
2. structural support for the crane foundation
3. ice strengthening to comply with ABS rules

#### Structural Support for Concentrated Deck Loads

The required deck plating thickness to support the concentrated sinker load was calculated using ABS rules 13.3 (Vessels Less Than 200 Feet) where:

$$t = s(h^{.5})/460 + .1$$

t = minimum deck thickness  
s = beam spacing = 24 for the conversion design  
h = head size = 12 ft for exposed deck  
carrying 540 lbs/sq feet

To account for a load greater than 540 lbs per square feet of deck space, the head size must be proportionally increased. The distributed load for a ten ton sinker is 622 lbs per square feet. Using this value, the head size is scaled:

$$h = 622/(540/12) = 13.82 \text{ feet}$$
$$t = 24*(13.82^{.5})/460 + .1 = .294 \text{ inches}$$

Since the existing deck thickness on the typical OSV is equal to .375 inches, this is adequate support for the concentrated sinker load.

To evaluate the maximum allowable load for a deck thickness of .375 inches, the thickness equation is solved for an equivalent h value. Then using this h value and the design ratio, a maximum

concentrated deck load is obtained:

$$t = s(h^{.5})/460 + .1$$

$$h = \{(.375 - .1) * 460 / 24\}^{.2} = 27.78$$

$$\text{max load} = (540/12)/27.78 = 1250 \text{ lbs per square feet}$$

As such the existing deck on the typical OSV will be capable of handling the expected concentrated loading for the conversion design.

As a check on this calculation, the existing sectional modulus on the typical OSV was calculated and compared to that required by the ABS rules. ABS Rules for vessels less than 200 feet, section 6.3, establish the minimum sectional modulus (SM) at amidships as:

$$SM = f * B * (Cb + .5) = 1161.8 \text{ inches squared feet}$$

with

$$f = \text{tabulated coefficient} = 27.3$$

$$B = \text{breadth in feet} = 38$$

$$Cb = \text{block coefficient} = .62$$

The existing SM on the typical OSV was computed using the longitudinal structural components. These calculations, included on the following table, indicate that the typical OSV has an existing sectional modulus of 2176.8 inches squared feet. This fact supports the data that the existing deck will support the buoy and sinker loads imposed by the conversion design.

#### Crane Support

At this stage of the design process, the most important data needed regarding the crane foundation support was the weight of such

structure. An estimate was made using similar ship data. This weight was estimated to equal ten tons.

### Ice Strengthening

The ABS rules, Section 29, for ice strengthening establish the following ice conditions for the various ice classes:

(A) Class IAA - Full winter operation in solid ice with a thickness of about 1 meter with an age of ice of one year; ice ridges may be several meters in depth. In heavy ice, the ice strengthened vessel would normally operate astern of an ice breaker.

(B) Class IA - Open broken ice operation with limited open water or ice flows with a thickness of 1 kilometer or less. The broken ice could be up to 1 meter thick.

(C) Class IC - Operation in small ice pieces with considerable open water.

The goal was to meet the requirements for Class IAA. The converted design fails to meet these standards for three reasons. First, Section 29.35.2 of the ABS Rules specifies a minimum frame thickness of .39 inches. The existing frames are only .3125 inches and the cost of reframing would be prohibitive. Secondly, an ice belt with a thickness of 1.4 inches of mild steel would be required. The additional weight would increase the displacement and draft beyond acceptable limits. Lastly, Section 29.25.1 requires a minimum SHP of 3500 SHP to be Class IAA. The installed main engines on a typical OSV are usually 2000 SHP and fall short of this requirement.

A check was made to see if the converted design met the requirements for Class IC. Again, the converted design was

inadequate on the basis of frame thickness and required ice belt. Even using high strength steel (HY-80) the ice belt would need to be .82 inches. Additionally, the bow angle of the converted design is 58 degrees and the ABS Rules specify that the angle be between 22 and 35 degrees.

It is concluded that the converted design does not meet the minimum requirements as specified by ABS for ice classification.



## Calculations to Determine the Sectional Modulus of the Typical OSV

The following table represents the members of a typical OSV's midship section which contribute to the ship's longitudinal strength:

Member	Scantline (inches)	Area (in sq)	dn (ft)	adn	a(dn**2)	i
bottom plate	.375x228	85.5	-7	-598.5	4189.5	0
sides	.375x144	54.0	0	0	0	648
long blhd	.3125x126	39.37	0	0	0	361.8
long	.3125x126	39.37	0	0	0	361.8
inner bottom plate	.1875x156	29.25	-5.3	-155.0	821.6	0
keel bar	1.5x8	12.0	-7.8	-93.0	720.8	0.44
main	.375x228	85.5	5.8	491.6	2826.8	0
summation		344.99		-354.9	8558.7	1371.9

Using the information from the preceding table, the typical OSV midship's sectional modulus is computed as follows:

i = vertical moment of inertia of each individual shape effective for longitudinal strength

dn = distance of the center of gravity of each shape from the assumed axis

a = area of each plate

Sa\*dn = Summation of all values for a \* dn = -354.9

Sa = Summation of all values for a = 344.99

Sa\*dn\*\* = Summation of all values for a \* dn \* dn = 8558.7

$dg$  = distance from the assumed axis to the true axis in feet =

$$Sa \cdot dn / Sa = -1.028$$

$Sa \cdot dg^{**}$  = Summation of all values for  $a \cdot dg \cdot dg = 365.1$

$I$  = Moment of Inertia =  $2 \cdot (Sa \cdot dn^{**} - Sa \cdot dg^{**}) = 8193.6$

$C$  = distance from the assumed neutral axis to the main deck =  
7.528

$SM$  = Section Modulus =  $I/C = 2177$  inches squared feet

## APPENDIX 6

### Speed and Power Calculations

Cedric Ridgely-Nevitt's paper, 'The Resistance of a High Displacement - Length Ratio Trawler Series' was used to predict the converted design's powering requirements at a range of operating speeds. These predictions are acceptable for ships with prismatic coefficients between .55 and .70 and displacement-length ratios between 200-500.

Using the paper as a guide with the following inputs, the following data was calculated. The speed power curve for the converted design is plotted and shows that the ship requires approximately 2000 SHP to operate at 13 knots.

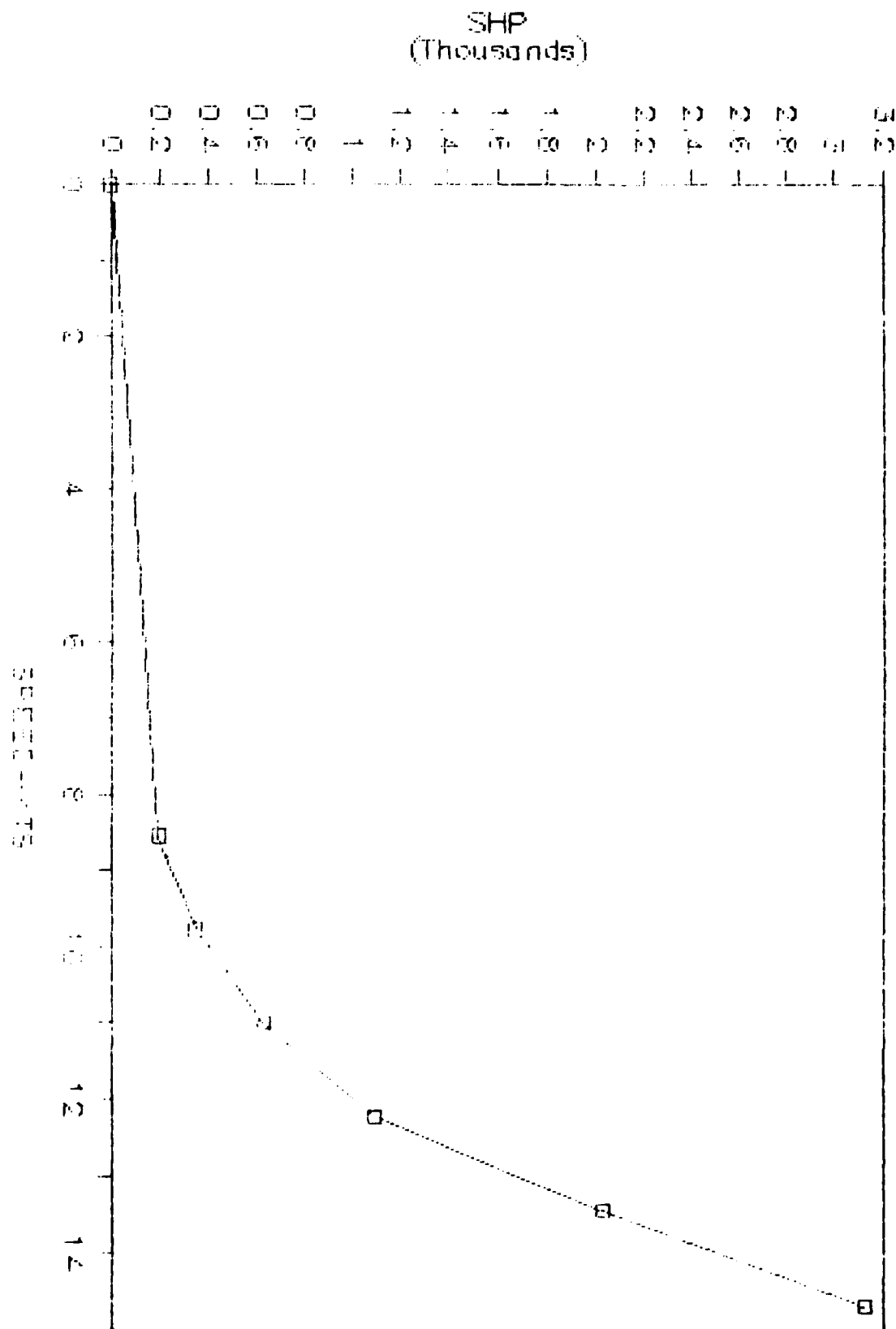
#### Input data:

prismatic coefficient = 0.70  
 block coefficient = 0.658  
 length (forward perpendicular to rudder post) = 149'  
 displacement = 922.3 tons  
 volume = 322280.5 cubic feet  
 displacement/length = displacement/(.01L) = 278.81  
 beam/draft = 4.2  
 wetted surface area =  $s = 2.8 * \text{volume} * \text{length}$  = 6140.7 sq feet  
 propulsive coefficient = 0.65

#### Output Data:

Speed knots	V/(L)	Cr (10**3)	Ct (10**3)	EHP	EHP corrected	SHP
8.54	0.7	1.3	3.63	120.9	128.2	197.2
9.77	0.8	1.9	4.2	209.6	226.4	348.3
10.99	0.9	2.75	5.02	356.1	405.9	624.5
12.21	1.0	4.5	6.74	655.7	708.2	1089.5
13.42	1.1	7.4	9.62	1242.1	1316.7	2025.7
14.65	1.2	8.8	10.99	1846.9	2031.6	3125.5

# OSV SPEED POWER CURVE



## APPENDIX 7

### Fuel Consumption

The following calculations show how the required fuel capacities for the converted design were determined.

Fuel Oil: Main Engines Specific Fuel Consumption (SFC)  
SFC = .42 lb per hp-hr  
Speed = 12.5 kts  
Horsepower = 2000

Main Engines

Fuel oil weight =  $.42 \text{ lb}/(\text{hp-hr}) \times (4000 \text{ nm}/12.5 \text{ kts}) \times 2000 \text{ HP}$   
= 268,800 lbs or 120 LT

Generators SFC = .55 lb per kw-hr

Fuel oil weight =  $.55 \text{ lb}/(\text{kw-hr}) \times 24 \text{ hrs} \times 21 \text{ days}$   
= 3366 lbs or 1.5 LT

## APPENDIX 8

### Electrical Generating Capacity Calculation

This appendix shows the calculation performed in accordance with SNAME T & R Bulletin 3 - 27 which figures the electrical generating capacity required for a vessel.

N : Number of crew members                      SHP = 2100

Required Kw =  $0.015 \text{ SHP} + 1.6N + 9(N^{.5}) + 80$   
                    = 250 Kw

This estimate compares favorably with similar ship information.

## APPENDIX 9

### Dynamic Stability

This appendix contains detailed information on the stability analysis of the converted design under various conditions. The stability of the vessel was checked for adequacy for a 100 knot beam wind, for lifting weight over the side, for towing and for a high speed turn.

From the SHCP computer program, a Righting Arm Curve was generated for the typical OSV for two conditions:

- a. Normal operating condition  
displacement = 1031 LT  
KG = 11.22 ft
- b. Minimum Operating Condition  
displacement = 855 LT  
KG = 12.45 ft

Using the stability criteria contained in the U.S. Navy Design Data Sheet 079.1, analysis was performed to determine whether the converted design met the requirements for adequate stability.

#### Wind Heeling:

The heeling arm due to wind is given by the equation:

$$\text{HEELING ARM} = \frac{.004 (V^{**2}) \times A \times L \times (\cosine O)^{**2}}{2240 \times \text{Displacement}}$$

where:

- A = projected sail area (sq ft)  
= 2900 sq ft
- L = lever arm from half draft  
to centroid of sail area (ft)  
= 18.5 ft
- V = wind velocity  
= 100 knots
- O = angle of inclination (degrees)

$$\text{Wind heeling arm (full load)} = .818 * (\cos O)^{**2}$$

Wind heeling arm (min op) =  $1.12 * (\cos 0)^{**2}$

### Weight Over The Side:

The weight over the side heeling arm equation is:

$$\text{HEELING ARM} = \frac{W \times a \times \cosine \ O}{\text{Displacement}}$$

where: W = weight of lift in ton  
 = 20 ton  
 a = transverse distance from centerline to end of boom foot.  
 = 44 ft

Heavy weight heeling arm (full load) =  $.854 * \cos 0$   
 Heavy weight heeling arm (min op) =  $1.12 * \cos 0$

### Towing:

The heeling arm for towing is given by the equation:

$$\text{HEELING ARM} = \frac{2 \times N \times (\text{SHP} \times D) \times .667 \times S \times h \times \cos \ O}{38 \times \text{Displacement}}$$

where: N = number of propellers = 2  
 SHP = shaft horsepower per shaft = 1000  
 D = propeller diameter (ft) = 7  
 S = stream deflection coefficient = .55  
 h = vertical distance from shaft centerline to towing bitts = 1.5 ft

Towing heeling arm (full load) =  $3.01 * \cos 0$   
 Towing heeling arm (light ship) =  $3.66 * \cos 0$

### High Speed Turns:

The heeling arm for high speed turns equation is:

$$\text{HEELING ARM} = \frac{V^{**2} \times a \times \cosine \ O}{g \times R}$$

where: a = distance between ship's TCG and half draft  
 = 22 ft  
 V = ship velocity = 12 kno or 20.26 ft/sec  
 R = one-half tactical diameter = 250 ft



High speed heeling arm (full load) =  $1.12 \cdot \cos 0$

The total correction for free surface effects were calculated below to equal  $.074 \cdot \cos 0$ .

FS = Free Surface Correction  
 $FS = (SGTL/SGW) \cdot (i/V)$

where

SGTL = specific gravity of tank liquid

= 0.923 for lube oil

= 0.837 for fuel oil

SGW = specific gravity of water

= 1.0

i = moment of inertia of the free surface area about the longitudinal axes through the centroid of the free surface area

=  $l \cdot (w^3) / 12$

l = tank length

w = tank width

V = volume of the displacement of the ship

= 36085 cubic feet

Tank	l	w	content	FSC
24-1	12	13	FO	0.05
24-2	12	13	FO	0.05
74-1	22	6	FO	0.02
74-2	22	6	FO	0.02
96-1	6	6	FO	0.007
96-2	6	6	FO	0.007
102-1	4	6	LO	0.002
102-2	4	6	LO	0.002
112-1	16	6	W	0.008
112-2	16	6	W	0.008
114-1	14	5	W	0.004
114-2	14	5	W	0.004
Summation				.15

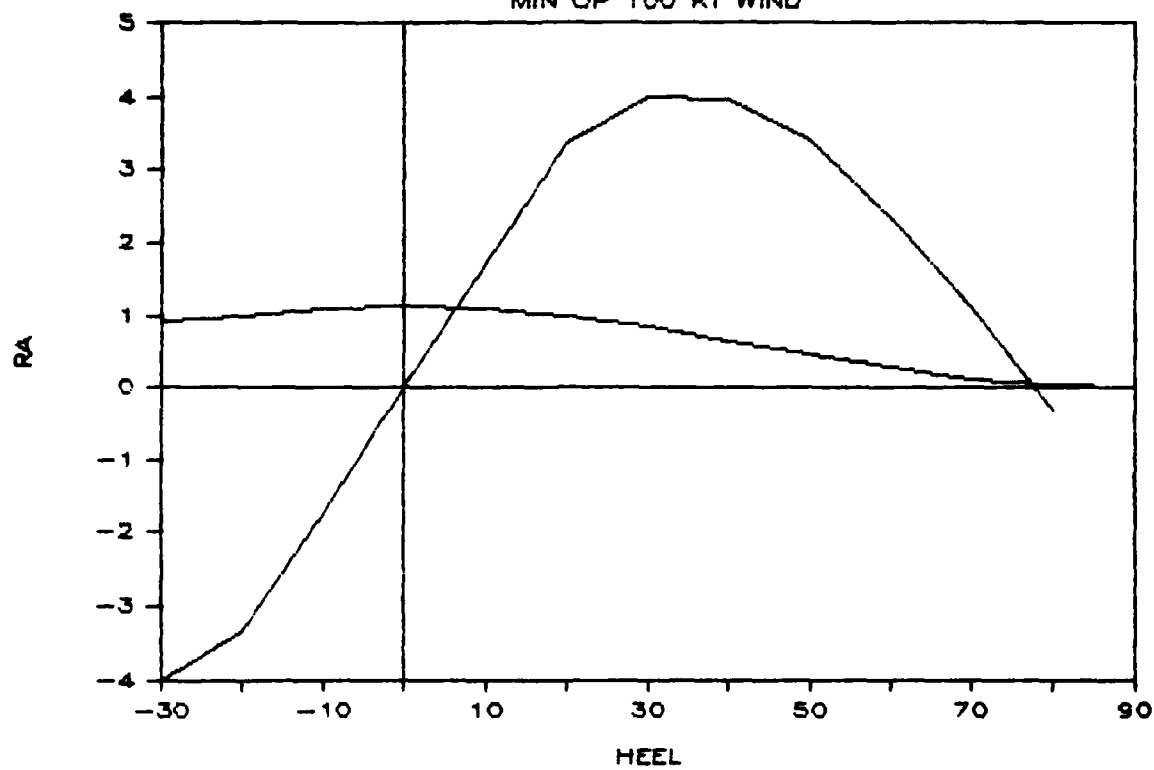
Free Surface Correction =  $.15 \cdot \sin 0$

# INTACT CURVES OF STATICAL STABILITY

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	DRAFT	TRIM
1031.100	-0.907	11.22	0.000	0.000	0.000	5.772	9.857	0.300
			10.000	1.711	2.657	6.002	9.801	0.086
			20.000	3.017	4.895	6.592	9.795	0.308
			30.000	3.846	6.645	7.402	9.885	1.920
			40.000	4.046	7.808	8.209	9.704	4.852
			50.000	3.614	8.450	8.848	9.432	9.374
			60.000	2.784	8.802	9.353	9.151	15.321
			70.000	1.735	9.011	9.786	8.582	27.789
			80.000	0.568	9.125	10.188	7.073	62.943
			90.000	****				
855.000	0.051	12.45	0.000	0.000	0.000	5.062	8.654	0.270
			10.000	1.743	3.026	5.325	8.556	-0.127
			20.000	3.363	5.895	6.087	8.347	-0.703
			30.000	4.006	7.797	6.958	7.986	-0.347
			40.000	3.962	9.048	7.831	7.175	1.106
			50.000	3.388	9.839	8.617	5.922	3.809
			60.000	2.366	10.281	9.247	4.105	7.359
			70.000	1.094	10.536	9.780	0.637	15.279
			80.000	-0.312	10.670	10.252	-9.353	38.140
			90.000	****				

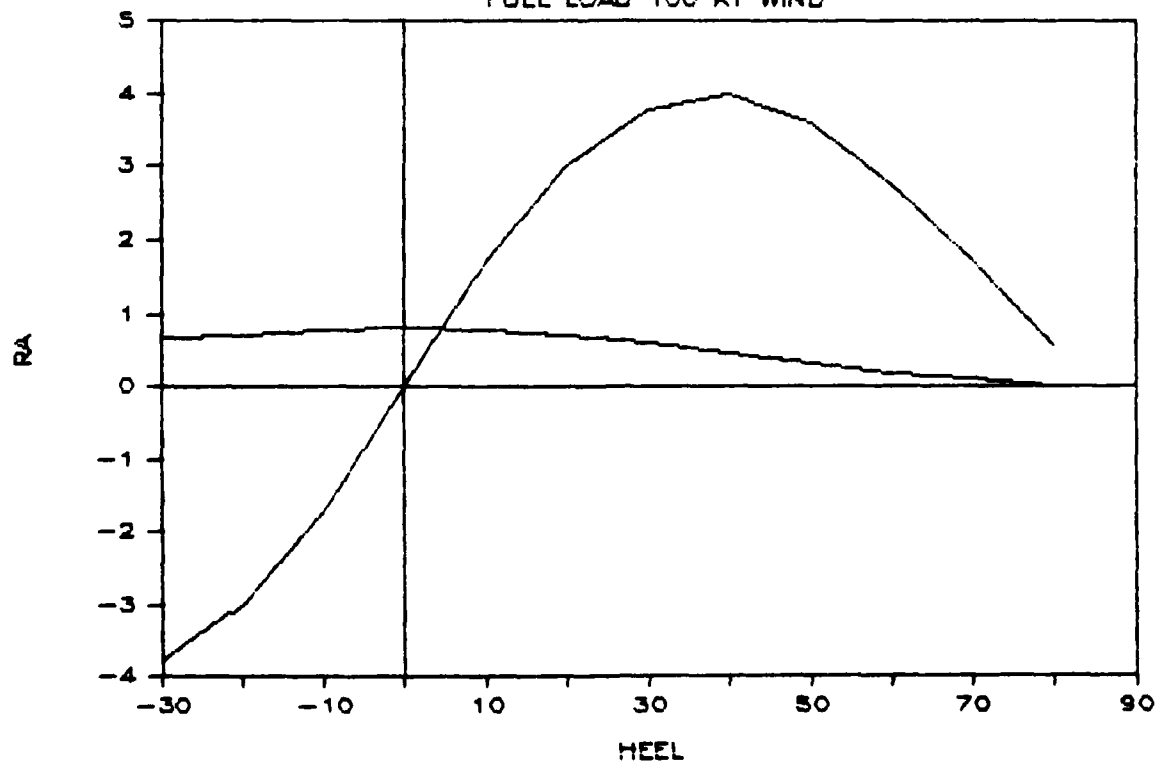
# RIGHTING ARM

MIN OP 100 KT WIND



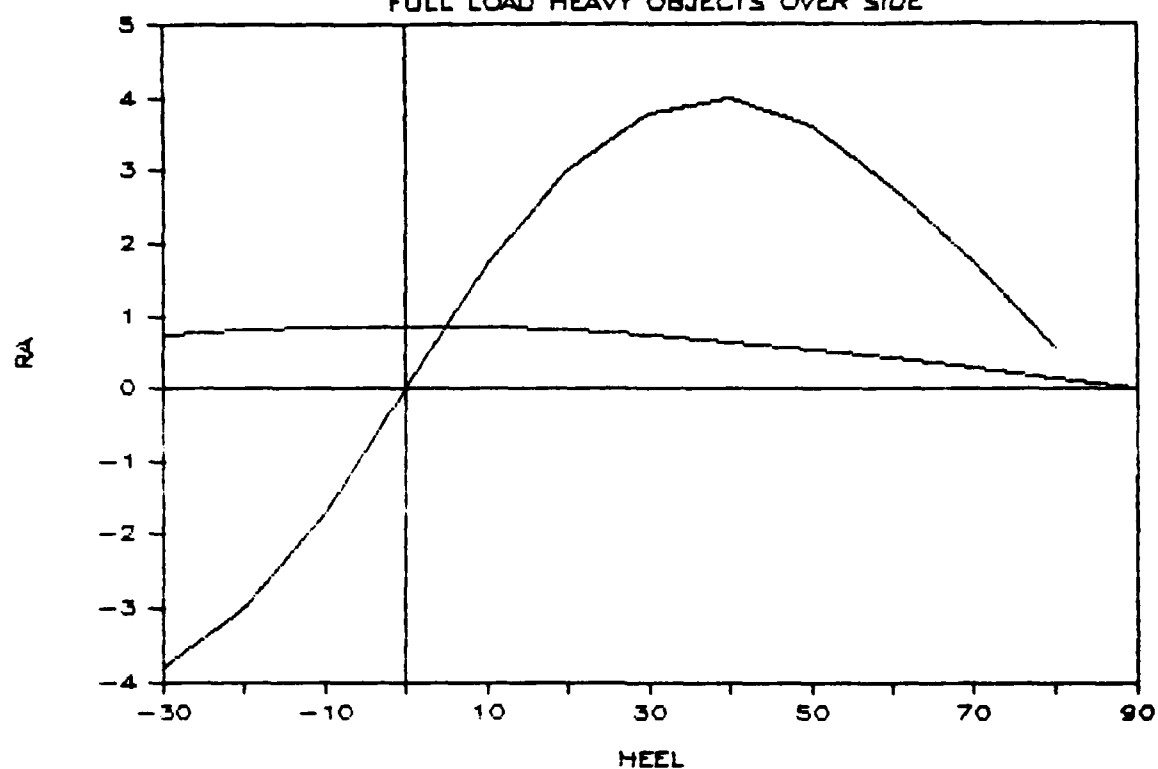
# RIGHTING ARM

FULL LOAD 100 KT WIND



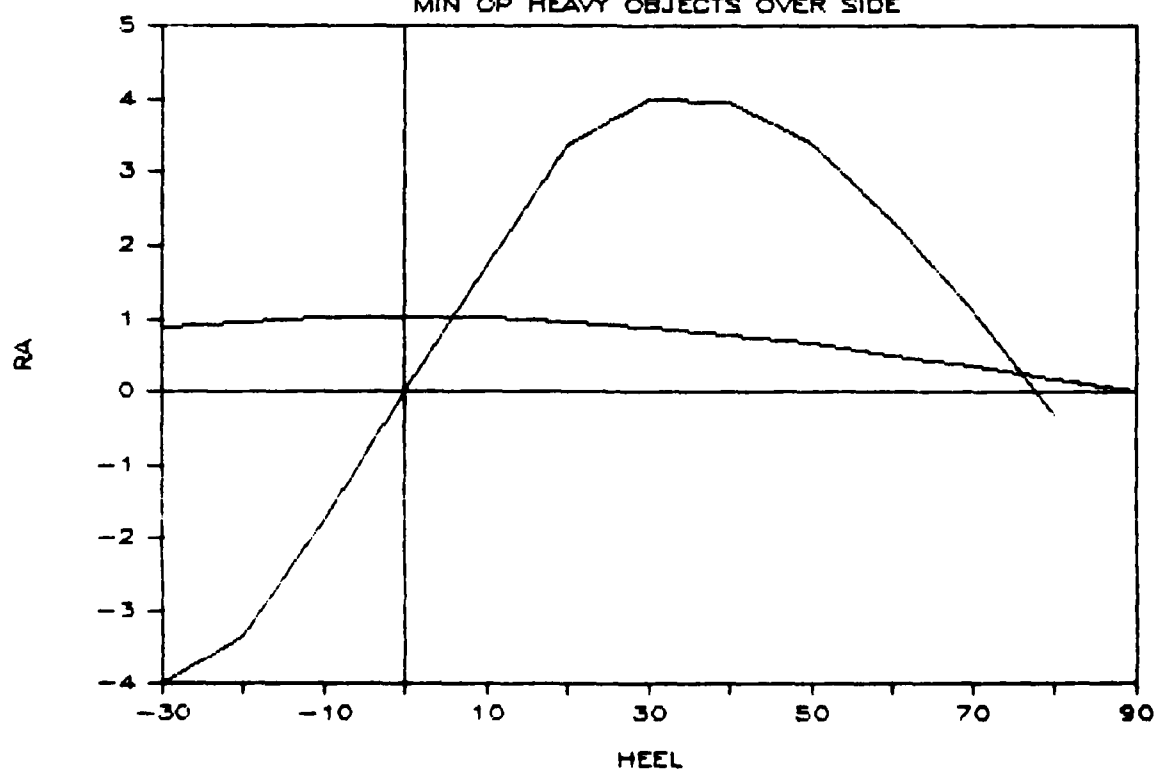
## RIGHTING ARM

FULL LOAD HEAVY OBJECTS OVER SIDE



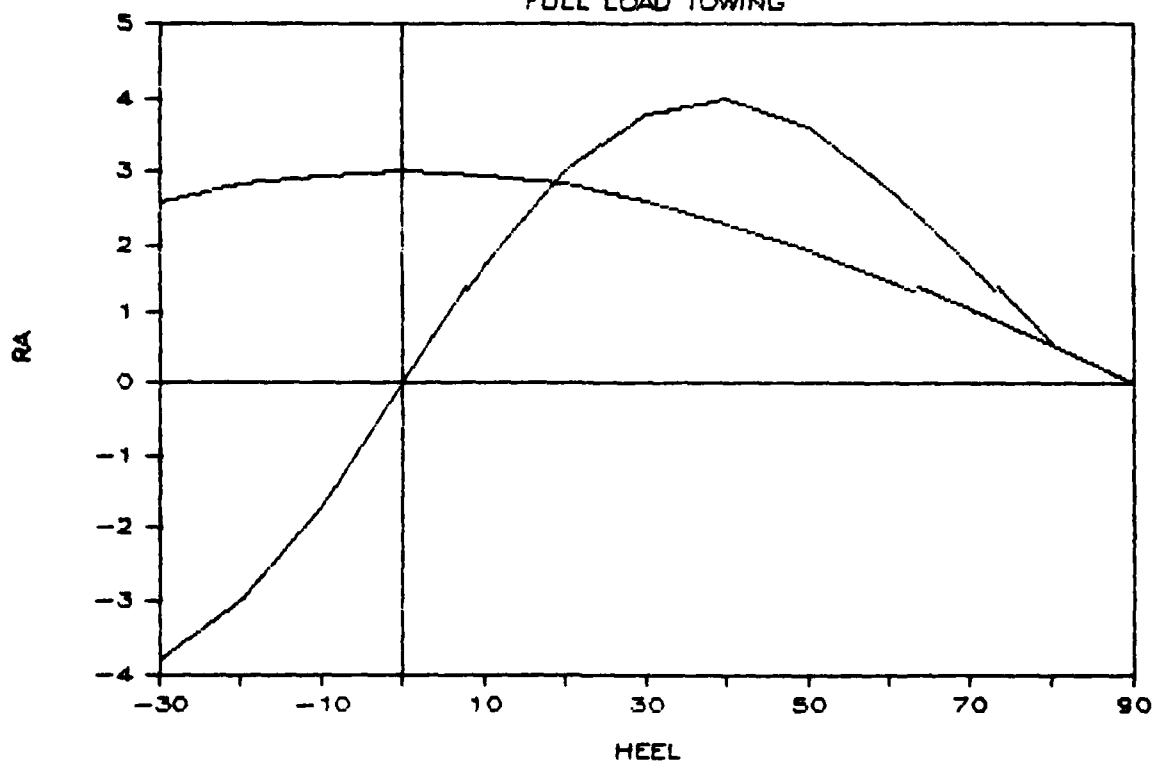
## RIGHTING ARM

MIN OP HEAVY OBJECTS OVER SIDE



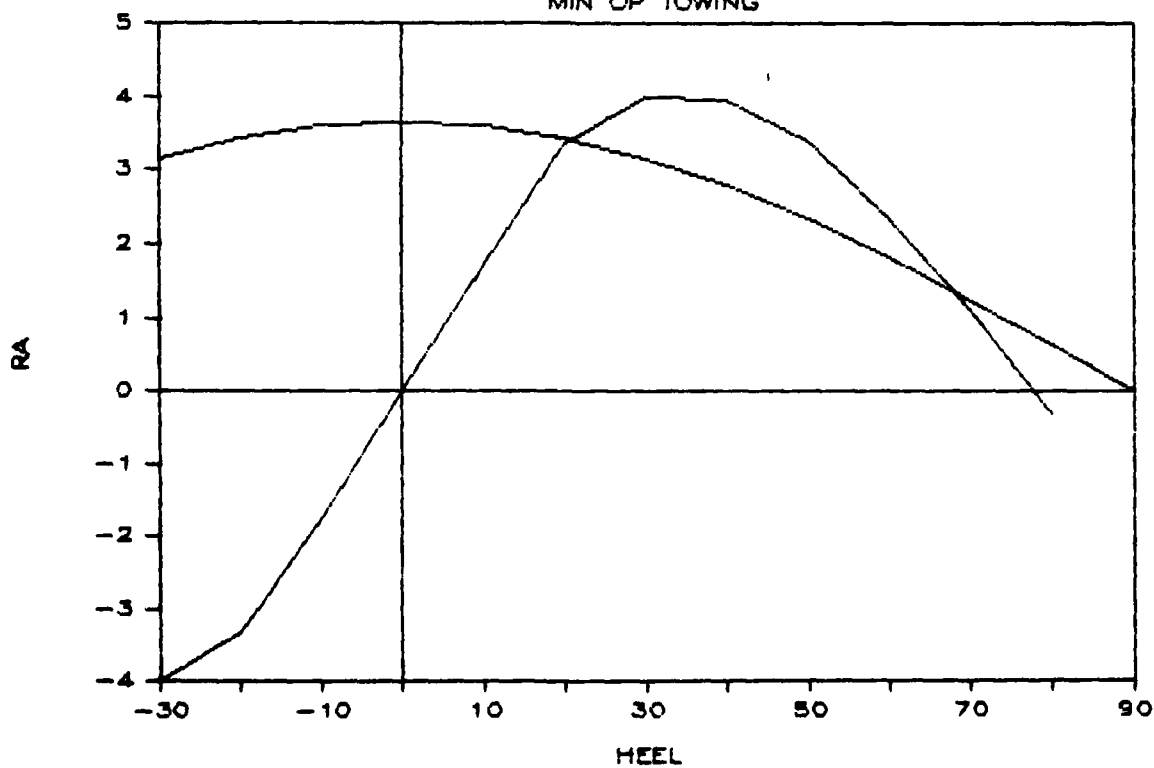
# RIGHTING ARM

FULL LOAD TOWING



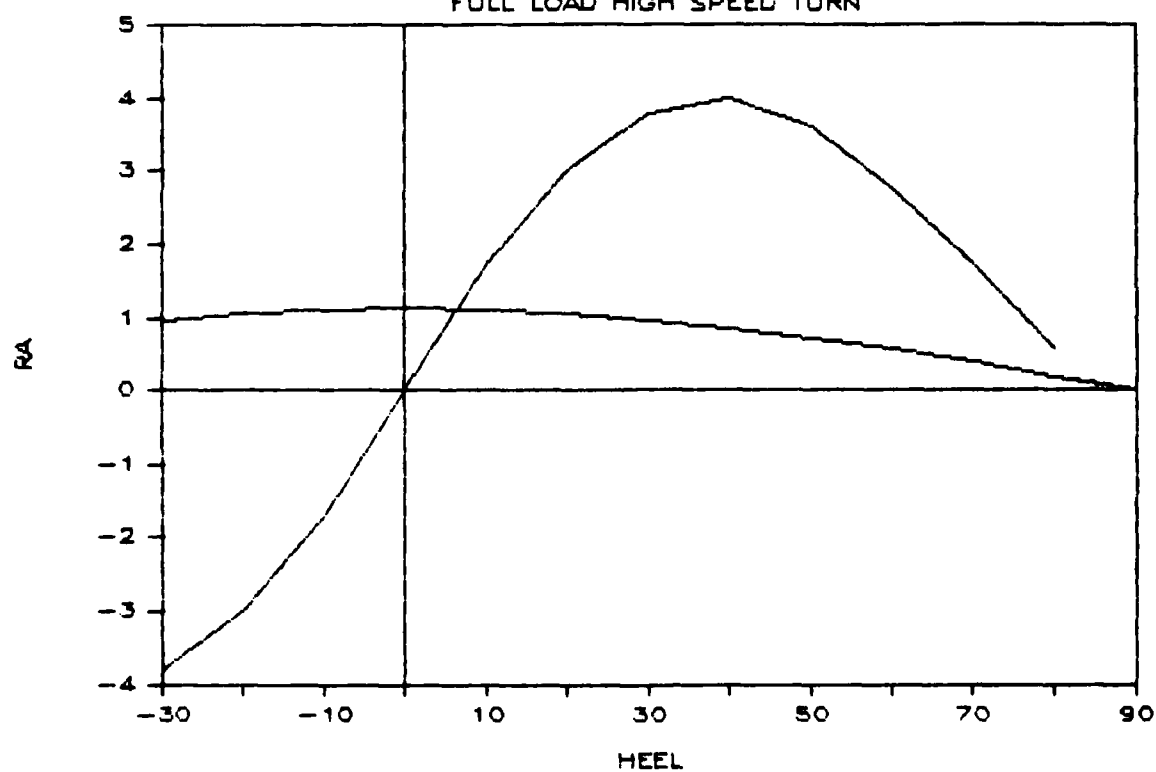
# RIGHTING ARM

MIN OP TOWING



# RIGHTING ARM

FULL LOAD HIGH SPEED TURN



## APPENDIX 10

### Floodable Length Calculations

Floodable length calculations were performed using the SHCP computer program for two different conditions:

Condition 1: Displacement = 1275 LT, Machinery deck watertight.

Condition 2: Displacement = 1031 LT, Machinery deck and main deck watertight.

Condition 1 was calculated for an initial estimate of the ship's floodable length characteristics. Condition 2 represents the design's current displacement and arrangement.

The resulting floodable length curves and the computer output are presented for each condition.

75  
85  
95

CONDITION I

A-1275  
2 DECK WT

50000 - 30000 - 10000



SHIP- OSV

SERIAL NUMBER- 0 DATE-01-16-86

DESIGN DISPLACEMENT 1275.000 TONS SW  
DESIGN LCG -1.630 FEET FROM AMIDSHIPS (+ FWD)  
DESIGN DRAFT 11.500 FEET  
DESIGN TRIM 0.000 FEET (+ BY STERN)  
  
LENGTH OVERALL 155.000 FEET  
LENGTH BETWEEN PERPENDICULARS 155.000 FEET  
LENGTH ON DESIGN WATERLINE 155.000 FEET  
  
STATION OF MAX AREA (AT DWL) 77.500 FEET FROM FP  
BEAM AT STATION OF MAX AREA 38.000 FEET  
SECTION AREA COEFFICIENT 0.9348  
PRISMATIC COEFFICIENT 0.7048  
BLOCK COEFFICIENT 0.6588

SHIP- OSV

SERIAL NUMBER- 0 DATE-01-16-86

FLOODABLE LENGTH CALCULATIONS - MARGIN LINE HEIGHTS

MARGIN LINE ASSUMED 3 INCHES BELOW UPPERMOST Z OF STATION.  
INPUT CHANGES INDICATED BY \*\*

STATION	DISTANCE FROM FP IN FEET	HEIGHT ABOVE BL IN FEET
0.000	0.00	22.54
0.500	7.75	22.38
1.000	15.50	22.17
1.500	23.25	22.11
2.000	31.00	21.85
3.000	46.50	21.46
4.000	62.00	21.46
5.000	77.50	21.46
6.000	93.00	13.25
7.000	108.50	13.25
8.000	124.00	13.25
8.500	131.75	13.25
9.000	139.50	13.25
9.500	147.25	13.25
10.000	155.00	13.25

MINIMUM PERMEABILITY 0.175

INPUT PERMEABILITY 0.950 0.850 0.750

SHIP- OSV

SERIAL NUMBER- 0 DATE-01-16-86

## FLOODABLE LENGTH AT 0.950 PERMEABILITY

LOCATION FT FROM FP	STATION	FLOODABLE LENGTH FEET	DRAFT FORWARD FEET	DRAFT AFT FEET
20.238	END POINT	40.476	22.540	7.034
23.250	1.500	36.568	21.984	7.427
27.125	1.750	32.589	21.057	8.046
31.000	2.000	29.275	20.255	8.580
34.875	2.250	27.013	19.539	9.058
38.750	2.500	25.627	18.885	9.493
42.625	2.750	24.646	18.271	9.903
46.500	3.000	23.859	17.696	10.286
50.375	3.250	23.252	17.149	10.651
54.250	3.500	22.791	16.626	10.999
58.125	3.750	22.430	16.125	11.333
62.000	4.000	22.134	15.644	11.654
65.875	4.250	21.868	15.182	11.962
69.750	4.500	21.602	14.738	12.258
73.625	4.750	21.305	14.312	12.542
77.500	5.000	20.972	13.903	12.814
81.375	5.250	20.621	13.511	13.076
85.250	5.500	19.492	13.065	13.250
89.125	5.750	17.113	12.576	13.250
93.000	6.000	15.205	12.200	13.250
96.875	6.250	13.666	11.903	13.250
100.750	6.500	12.437	11.663	13.250
104.625	6.750	11.516	11.465	13.250
108.500	7.000	10.859	11.298	13.250
112.375	7.250	10.427	11.156	13.250
116.250	7.500	10.204	11.033	13.250
120.125	7.750	10.200	10.927	13.250
124.000	8.000	10.462	10.834	13.250
127.875	8.250	11.000	10.753	13.250
131.750	8.500	11.822	10.679	13.250
135.625	8.750	12.921	10.614	13.250
139.500	9.000	14.221	10.555	13.250
143.375	9.250	15.681	10.502	13.250
146.500	END POINT	16.946	10.463	13.250

SHIP- OSV

SERIAL NUMBER- 0 DATE-01-16-86

## FLOODABLE LENGTH AT 0.850 PERMEABILITY

LOCATION FT FROM FP	STATION	FLOODABLE LENGTH FEET	DRAFT FORWARD FEET	DRAFT AFT FEET
21.781	END POINT	43.563	21.879	7.497
23.250	1.500	41.366	21.658	7.645
27.125	1.750	36.821	20.888	8.158
31.000	2.000	33.209	20.137	8.658
34.875	2.250	30.446	19.489	9.091
38.750	2.500	28.786	18.863	9.508
42.625	2.750	27.652	18.258	9.911
46.500	3.000	26.771	17.688	10.291
50.375	3.250	26.081	17.144	10.654
54.250	3.500	25.545	16.624	11.001
58.125	3.750	25.119	16.124	11.334
62.000	4.000	24.767	15.644	11.654
65.875	4.250	24.454	15.182	11.962
69.750	4.500	24.144	14.738	12.258
73.625	4.750	23.812	14.312	12.542
77.500	5.000	23.439	13.903	12.814
81.375	5.250	23.047	13.511	13.076
85.250	5.500	21.785	13.064	13.250
89.125	5.750	19.110	12.575	13.250
93.000	6.000	16.994	12.200	13.250
96.875	6.250	15.283	11.903	13.250
100.750	6.500	13.919	11.664	13.250
104.625	6.750	12.889	11.465	13.250
108.500	7.000	12.154	11.299	13.250
112.375	7.250	11.672	11.156	13.250
116.250	7.500	11.426	11.034	13.250
120.125	7.750	11.420	10.928	13.250
124.000	8.000	11.714	10.836	13.250
127.875	8.250	12.311	10.754	13.250
131.750	8.500	13.226	10.682	13.250
135.625	8.750	14.441	10.617	13.250
139.500	9.000	15.880	10.557	13.250
143.375	9.250	17.485	10.504	13.250
145.737	END POINT	18.526	10.475	13.250

SHIP- OSV

SERIAL NUMBER- 0 DATE-01-16-86

## FLOODABLE LENGTH AT 0.750 PERMEABILITY

LOCATION FT FROM FP	STATION	FLOODABLE LENGTH FEET	DRAFT FORWARD FEET	DRAFT AFT FEET
23.613	END POINT	47.225	21.133	7.995
27.125	1.750	42.334	20.645	8.320
31.000	2.000	38.274	19.981	8.762
34.875	2.250	35.000	19.409	9.144
38.750	2.500	32.871	18.823	9.535
42.625	2.750	31.499	18.237	9.925
46.500	3.000	30.495	17.674	10.301
50.375	3.250	29.691	17.136	10.659
54.250	3.500	29.054	16.619	11.004
58.125	3.750	28.542	16.123	11.335
62.000	4.000	28.115	15.644	11.654
65.875	4.250	27.737	15.183	11.961
69.750	4.500	27.377	14.739	12.257
73.625	4.750	27.001	14.313	12.541
77.500	5.000	26.585	13.904	12.814
81.375	5.250	26.120	13.511	13.076
85.250	5.500	24.659	13.064	13.250
89.125	5.750	21.658	12.574	13.250
93.000	6.000	19.260	12.200	13.250
96.875	6.250	17.338	11.903	13.250
100.750	6.500	15.806	11.664	13.250
104.625	6.750	14.637	11.466	13.250
108.500	7.000	13.802	11.299	13.250
112.375	7.250	13.257	11.157	13.250
116.250	7.500	12.972	11.036	13.250
120.125	7.750	12.978	10.930	13.250
124.000	8.000	13.313	10.838	13.250
127.875	8.250	13.981	10.757	13.250
131.750	8.500	15.012	10.685	13.250
135.625	8.750	16.366	10.621	13.250
139.500	9.000	17.965	10.561	13.250
143.375	9.250	19.757	10.507	13.250
144.780	END POINT	20.440	10.490	13.250

SHIP- OSV

SERIAL NUMBER- 1 DATE-01-29-86

DESIGN DISPLACEMENT 1031.000 TONS SW  
DESIGN LCG -0.125 FEET FROM AMIDSHIPS (+ FWD)  
DESIGN DRAFT 9.790 FEET  
DESIGN TRIM 0.250 FEET (+ BY STERN)

LENGTH OVERALL 155.000 FEET  
LENGTH BETWEEN PERPENDICULARS 155.000 FEET  
LENGTH ON DESIGN WATERLINE 154.994 FEET

STATION OF MAX AREA (AT DWL) 98.133 FEET FROM FP  
BEAM AT STATION OF MAX AREA 38.000 FEET  
SECTION AREA COEFFICIENT 0.9349  
PRISMATIC COEFFICIENT 0.6671  
BLOCK COEFFICIENT 0.6237

SHIP- OSV

SERIAL NUMBER- 1 DATE-01-29-86

FLOODABLE LENGTH CALCULATIONS - MARGIN LINE HEIGHTS

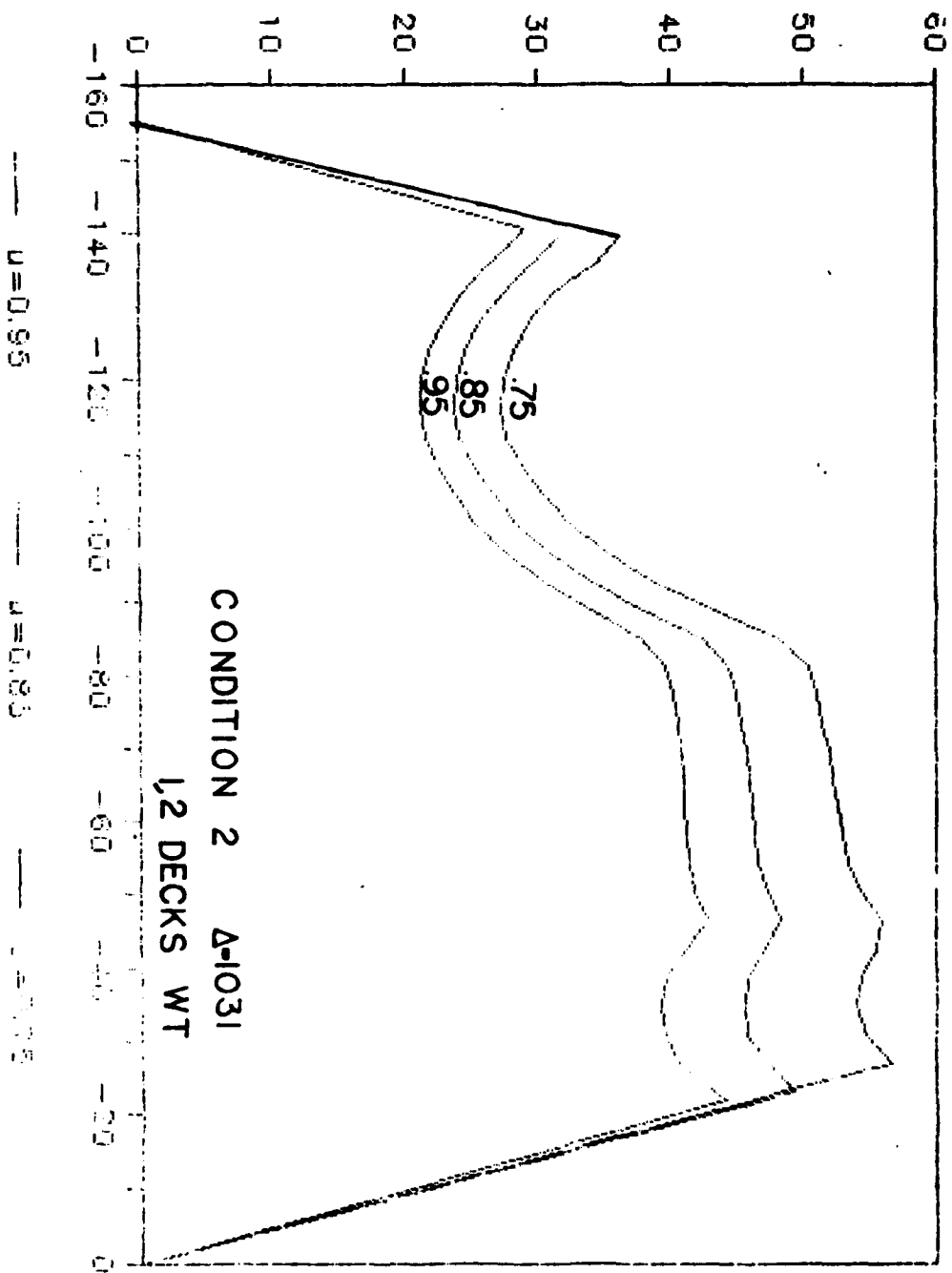
MARGIN LINE ASSUMED 3 INCHES BELOW UPPERMOST 2 OF STATION.  
INPUT CHANGES INDICATED BY \*\*

STATION	DISTANCE FROM FP IN FEET	HEIGHT ABOVE BL IN FEET
0.000	0.00	22.54
0.500	7.75	22.38
1.000	15.50	22.17
1.500	23.25	22.11
2.000	31.00	21.85
3.000	46.50	21.46
4.000	62.00	21.46
5.000	77.50	21.46
6.000	93.00	13.25
7.000	108.50	13.25
8.000	124.00	13.25
8.500	131.75	13.25
9.000	139.50	13.25
9.500	147.25	13.25
10.000	155.00	13.25

MINIMUM PERMEABILITY 0.341

INPUT PERMEABILITY 0.950 0.850 0.750

# FLOODABLE LENGTH



SHIP- OSV

SERIAL NUMBER- 1 DATE-01-29-86

## FLOODABLE LENGTH AT 0.950 PERMEABILITY

LOCATION FT FROM FP	STATION	FLOODABLE LENGTH FEET	DRAFT FORWARD FEET	DRAFT AFT FEET
21.981	END POINT	43.962	22.540	3.901
23.250	1.500	42.628	22.540	3.979
27.125	1.750	40.199	22.540	4.315
31.000	2.000	39.293	22.540	4.755
34.875	2.250	39.367	22.540	5.265
38.750	2.500	40.237	22.540	5.838
42.625	2.750	41.800	22.540	6.477
46.500	3.000	43.371	22.285	7.226
50.375	3.250	42.518	20.901	8.149
54.250	3.500	42.002	19.730	8.930
58.125	3.750	41.799	18.751	9.582
62.000	4.000	41.684	17.836	10.193
65.875	4.250	41.571	16.955	10.780
69.750	4.500	41.416	16.099	11.350
73.625	4.750	41.171	15.269	11.904
77.500	5.000	40.792	14.462	12.442
81.375	5.250	40.266	13.683	12.962
85.250	5.500	37.894	12.749	13.250
89.125	5.750	33.793	11.795	13.250
93.000	6.000	30.413	11.062	13.250
96.875	6.250	27.637	10.482	13.250
100.750	6.500	25.355	10.007	13.250
104.625	6.750	23.543	9.618	13.250
108.500	7.000	22.200	9.291	13.250
112.375	7.250	21.320	9.013	13.250
116.250	7.500	20.891	8.773	13.250
120.125	7.750	20.936	8.567	13.250
124.000	8.000	21.449	8.387	13.250
127.875	8.250	22.453	8.230	13.250
131.750	8.500	23.933	8.091	13.250
135.625	8.750	25.782	7.966	13.250
139.500	9.000	27.908	7.852	13.250
140.699	END POINT	28.602	7.818	13.250

SHIP- USV

SERIAL NUM

BER- 1 DATE-01-29-86

## FLOODABLE LENGTH AT 0.850 PERMEABILITY

LOCATION FT FROM FP	STATION	FLOODABLE LENGTH FEET	DRAFT FORWARD FEET	DRAFT AFT FEET
24.527	END POINT	49.053	22.540	4.268
27.125	1.750	46.832	22.540	4.458
31.000	2.000	45.347	22.540	4.860
34.875	2.250	45.188	22.540	5.344
38.750	2.500	45.999	22.540	5.899
42.625	2.750	47.621	22.540	6.522
46.500	3.000	49.075	22.220	7.270
50.375	3.250	47.988	20.871	8.169
54.250	3.500	47.317	19.718	8.938
58.125	3.750	47.016	18.747	9.585
62.000	4.000	46.812	17.837	10.192
65.875	4.250	46.620	16.959	10.777
69.750	4.500	46.389	16.105	11.346
73.625	4.750	46.062	15.274	11.901
77.500	5.000	45.606	14.465	12.440
81.375	5.250	45.029	13.684	12.961
85.250	5.500	42.399	12.749	13.250
89.125	5.750	37.820	11.795	13.250
93.000	6.000	34.069	11.063	13.250
96.875	6.250	30.990	10.484	13.250
100.750	6.500	28.464	10.011	13.250
104.625	6.750	26.461	9.622	13.250
108.500	7.000	24.961	9.297	13.250
112.375	7.250	23.978	9.020	13.250
116.250	7.500	23.520	8.782	13.250
120.125	7.750	23.580	8.576	13.250
124.000	8.000	24.149	8.399	13.250
127.875	8.250	25.266	8.243	13.250
131.750	8.500	26.860	8.105	13.250
135.625	8.750	28.837	7.981	13.250
139.458	END POINT	31.085	7.869	13.250



SHIP- OSV

SERIAL NUMBER- 1 DATE-01-29-86

## FLOODABLE LENGTH AT 0.750 PERMEABILITY

LOCATION FT FROM FP	STATION	FLOODABLE LENGTH FEET	DRAFT FORWARD FEET	DRAFT AFT FEET
28.202	END POINT	56.405	22.540	4.833
31.000	2.000	54.415	22.540	5.059
34.875	2.250	53.599	22.540	5.491
38.750	2.500	54.189	22.540	6.014
42.625	2.750	55.771	22.540	6.613
46.500	3.000	56.682	22.085	7.360
50.375	3.250	55.204	20.806	8.213
54.250	3.500	54.261	19.689	8.958
58.125	3.750	53.793	18.734	9.594
62.000	4.000	53.452	17.833	10.194
65.875	4.250	53.132	16.961	10.776
69.750	4.500	52.766	16.109	11.344
73.625	4.750	52.306	15.277	11.899
77.500	5.000	51.753	14.469	12.438
81.375	5.250	51.112	13.688	12.958
85.250	5.500	48.174	12.754	13.250
89.125	5.750	42.994	11.798	13.250
93.000	6.000	38.765	11.067	13.250
96.875	6.250	35.306	10.490	13.250
100.750	6.500	32.476	10.017	13.250
104.625	6.750	30.231	9.630	13.250
108.500	7.000	28.541	9.306	13.250
112.375	7.250	27.437	9.030	13.250
116.250	7.500	26.941	8.794	13.250
120.125	7.750	27.018	8.590	13.250
124.000	8.000	27.663	8.416	13.250
127.875	8.250	28.903	8.261	13.250
131.750	8.500	30.624	8.124	13.250
135.625	8.750	32.743	8.001	13.250
137.925	END POINT	34.149	7.934	13.250

## APPENDIX 11

### Seakeeping and Motions

Seakeeping and motion predictions are presented in two forms; a computer generated seakeeping estimation and similar ship data.

This appendix provides some background information on the Bales Seakeeping Program used in this report to estimate the converted design's seakeeping. The program, based on work done by Nathan Bales, calculates the relative seakeeping performance of a defined ship hullform. This performance criteria, known as BaleSeakeeping Rank Estimator, R, is based on the following equation.

$$R = 8.42 + 45.1 * CWPF + 10.1 * CWPA - 37.8 * (T / L) + 1.27 * (C / L) - 23.5 * CVPF - 15.9 * CVPA$$

where: CWPF = waterplane coefficient forward of midships  
CWPA = waterplane coefficient aft of midships  
T = draft  
L = length between perpendiculars  
C = cutup point, distance aft of the forward perpendicular where the keel rises  
CVPF = vertical prismatic coefficient forward  
CVPA = vertical prismatic coefficient aft

Bale's Rank Estimator can have values between 0 and 10, with 10 indicating the best seakeeping performance.

In addition to calculation of R factor, the following values are also calculated:

- Sectional areas for input stations
- Interpolated values for 21 evenly spaced stations:
  - station number
  - distance aft of the forward perpendicular
  - design waterline offset
  - sectional area
- Area of the waterplane forward/aft of amidships
- Waterplane coefficients forward/aft of amidships
- Displaced volume forward/aft of amidships
- Vertical prismatic coefficient forward/aft of amidships

- Cutup point

Additionally, if R is not satisfactory, the program will give recommendations for further improvements on the seakeeping characteristics of the hull.

Similar ship data allows a comparison for the converted design's seakeeping potential. Such data, from John C. Daidola's paper "Space Shuttle Booster Retrieval Platform for the United States Air Force", is presented below for a 190 foot, 1400 ton OSV in sea state 4 beam seas:

Natural Period of Roll = 4.8 sec  
Natural Period of Pitch = 5.6 sec

H 1/10 = 8 ft                      Forward speed = 4 knots  
Response measured = A 1/10

Wave period (sec)	6	7	8	9	10
Heave (ft)	3.8	3.8	3.8	3.8	3.8
Pitch	-	-	-	-	-
Roll (degrees)	14.5	11.5	9.2	8.0	6.3
Sway (ft)	-	-	-	-	3.9

H 1/10 = 5 ft                      Forward speed = 4 knots  
Responss measured = A 1/10

Wave period (sec)	6	7	8	9	10
Heave (ft)	2.4	2.4	2.4	2.4	2.4
Pitch	-	-	-	-	-
Rolll (degrees)	8.6	7.1	6.0	4.9	4.0
Sway (ft)	1.9	2.1	2.2	2.3	2.4

Computer analysis of an OSV hull form indicate the following motions in a seaway:

Heading	0	45	90	135	180
<hr/>					
Sea State 2					
Heave (ft)	.03	.04	.43	.07	.04
Pitch (deg)	.09	.10	.10	.14	.10
Sway (ft)		.02	.13	.03	
Roll (deg)		.22	1.9	.22	
Yaw (deg)		.05	.1	.06	
Sea State 3					
H	.74	1.3	3.5	1.3	.78
P	1.78	2.3	.2	2.8	2.5
S		1.0	3.4	1.0	
R		4.3	20.9	5.0	
Y		1.1	.6	1.3	
Sea State 4					
H	4.06	5.33	8.26	5.33	3.94
P	5.72	5.72	.26	6.48	6.48
S		3.81	8.0	3.68	
R		8.76	31.88	9.65	
Y		3.1	.9	3.30	
Sea State 6					
H	13.72	159	18.54	15.37	13.59
P	12.32	10.67	.25	11.56	
S		10.67	.26	10.67	
Y		6.1	1.14	6.62	

Note: 180 denotes head seas

BALES SEAKEEPING EQUATION IS:

$$R = 8.42 + 45.1CWPF + 10.1CWPA - 37.8(T/L) + 1.27(C/L) - 23.5CVPF - 15.9CVPA$$

BALES SEAKEEPING RANK ESTIMATOR FOR THIS SET OF OFFSETS IS  $R = 8.03$

THE TERMS OF BALES EQUATION ARE:

$45.1 * CWPF$	$=$	35.01
$10.1 * CWPA$	$=$	9.69
$37.8 * (T/L)$	$=$	2.32
$1.27 * (C/L)$	$=$	0.87
$23.5 * CVPF$	$=$	18.75
$15.9 * CVPA$	$=$	10.14

BALES EMPIRICALLY DERIVED HIS EQUATION BASED ON 20 OPERATING  
USN DESTROYER TYPE HULLS.

LISTED IN THE FOLLOWING TABLE ARE:

1. BEST CASE -- THAT VALUE OF THE GIVEN COEFFICIENT FROM THE DATA BASE WHICH MAXIMIZES BALES ESTIMATOR.
2. WORST CASE -- THAT VALUE OF THE GIVEN COEFFICIENT FROM THE DATA BASE WHICH MINIMIZES BALES ESTIMATOR.
3. CONSTANT -- THE CONSTANT WHICH MULTIPLIES THE GIVEN COEFFICIENT IN BALES EQUATION.
4. POTENTIAL CHANGE -- THE POTENTIAL CHANGE TO BALES ESTIMATOR IS BASED ON THE DIFFERENCE OF THE BEST CASE AND WORST CASE OF THE GIVEN COEFFICIENT, MULTIPLIED BY ITS RESPECTIVE CONSTANT. THIS POTENTIAL CHANGE FACTOR SHOULD BE A CONSIDERATION WHEN EVALUATING ANY RECOMMENDATIONS.

5. CALCULATED VALUE -- THE VALUE CALCULATED FROM THE GIVEN SET OF OFFSETS.

6. PERCENTAGE -- IF THE WORST CASE VALUE IS A MINIMUM, THEN  
PERCENTAGE = CALC. VALUE/WORST CASE VALUE

IF THE WORST CASE VALUE IS A MAXIMUM, THEN  
PERCENTAGE = WORST CASE VALUE/CALC. VALUE.

IF PERCENTAGE IS LESS THAN 1.0, THEN SUGGESTIONS ARE OFFERED FOR  
IMPROVING THE GIVEN COEFFICIENT.

IF PERCENTAGE IS GREATER THAN 1.0, THEN THE CALCULATED VALUE IS  
BETTER THAN THE WORST CASE.

SHIP---OSV

SERIAL NUMBER-- 1

	BEST CASE	WORST CASE	CONSTANT	POTENTIAL CHANGE	CALCULATED VALUE	PERCENTAGE
CWPF	.698	.565	+45.1	5.999	0.776	1.37
T/L	.0315	.0411	-37.8	3.633	0.061	0.67
CVPF	.677	.807	-23.5	3.055	0.798	1.01
CVPA	.551	.690	-15.9	2.207	0.638	1.08
CWPA	.927	.834	+10.1	0.887	0.960	1.15
C/L	.850	.600	+ 1.27	0.318	0.689	1.15

## APPENDIX 12

### Trimlines After Compartment Flooding

To evaluate the actual effects of compartment flooding, the TRIMLINES portion of SHCP was used to determine the forward, amidships, and aft drafts when specified compartments were flooded.

The specific compartment locations and their associated permeabilities are input as a data file into the program. This data is contained in the table below. Variations to the accepted permeation values for specific compartments account for the presence of wing tanks surrounding the compartment. Flooding is calculated as extending from side-shell to side-shell.

Compartment	Primary Use	Frame Location	Permeability
1	Fore Peak Tank	0 - 10	.10
2	Forward Ballast	10 - 24	.10
3	Bow Thruster Room	24 - 48	.65
4	Berthing	48 - 74	.95
5	Eng. Work Space	74 - 95	.95
6	Main Engine Room	95 - 126	.85
7	Stores	126 - 142	.85
8	After Steering	142 - 150	.85
9	Ballast Tank	150 - 155	.10

Compartments Flooded In Damaged Condition	Resulting Condition
1	Survives
2	Survives
3	Survives
4	Survives
5	Survives
6	Flounders
7	Survives
8	Survives
9	Survives
1 and 2	Survives

2 and 3	Survives
3 and 4	Amidships Awash
4 and 5	Amidships Awash
5 and 6	Flounders
6 and 7	Flounders
7 and 8	Survives
8 and 9	Survives
1,2 and 3	Survives
2,3 and 4	Amidships Awash
3,4 and 5	Flounders
4,5 and 6	Flounders
5,6 and 7	Flounders
7,8 and 9	Survives

In summary, the calculations agree with the predictions made in the floodable length segment of the project. As predicted, if the engine room floods, the margin line becomes submerged. The same scenario follows for any combination of adjacent compartments whose total length exceeds the allowable lengths at their mid-distance. The calculations for the resulting trimlines due to damage in all cases agree with the allowable floodable length calculations.

The following computer output was used to predict the ships survivability. It is noted that a blank response or a "NO BALANCE" response indicates a condition at which the ship does not remain afloat.



SHIP-OSV

SERIAL NUMBER- 1 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 1

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
1	0.000	10.000	0.100

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1031.727 TONS SW  
LONGL C.G. -0.777 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 9.865 FEET  
DRAFT AT FP 9.757 FEET  
DRAFT AT AP 9.973 FEET

TOTAL TRIM 0.216 FEET

FLOODED WATER 0.727 TONS SW

LCG OF FLD.WTR. 71.141 FEET FROM AMIDSHIPS (+ FWD)  
SHIP-OSV SERIAL NUMBER- 1 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 2

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
2	10.000	24.000	0.100

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1034.601 TONS SW  
LONGL C.G. -0.621 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 9.889 FEET  
DRAFT AT FP 9.835 FEET  
DRAFT AT AP 9.942 FEET

TOTAL TRIM 0.107 FEET

FLOODED WATER 3.601 TONS SW  
LCG OF FLD.WTR. 58.438 FEET FROM AMIDSHIPS (+ FWD)  
SHIP-OSV SERIAL NUMBER- 1 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMP

# ARTMENTS FOR CONDITION 3

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
3	24.000	48.000	0.650

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1183.233 TONS SW  
 LONGL C.G. 4.521 FEET FROM AMIDSHIPS (+ FWD)  
 DRAFT AMIDSHIPS 11.060 FEET  
 DRAFT AT FP 13.231 FEET  
 DRAFT AT AP 8.889 FEET

TOTAL TRIM -4.342 FEET

FLOODED WATER 152.233 TONS SW  
 LCG OF FLD.WTR. 40.745 FEET FROM AMIDSHIPS (+ FWD)  
 SHIP-OSV SERIAL NUMBER- 1

DATE-01-29-86

## TRIM LINE CALCULATIONS

# DAMAGED COMPARTMENTS FOR CONDITION 4

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
4	48.000	74.000	0.950

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1342.942 TONS SW  
 LONGL C.G. 3.203 FEET FROM AMIDSHIPS (+ FWD)  
 DRAFT AMIDSHIPS 12.127 FEET  
 DRAFT AT FP 14.238 FEET  
 DRAFT AT AP 10.016 FEET

TOTAL TRIM -4.222 FEET

FLOODED WATER 311.942 TONS SW  
 LCG OF FLD.WTR. 16.525 FEET FROM AMIDSHIPS (+ FWD)  
 SHIP-OSV SERIAL NUMBER- 1

DATE-01-29-86

## TRIM LINE CALCULATIONS

AD-A168 981

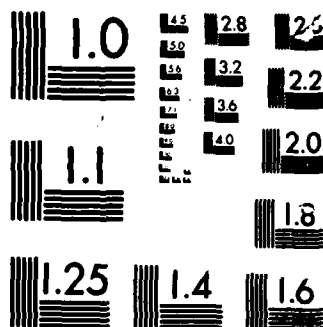
OFFSHORE SUPPLY VESSEL TO BUOY TENDER CONVERSION DESIGN 2/2  
(U) MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF OCEAN  
ENGINEERING L BOWLING ET AL. MAR 86 USCG-D-6-86

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UNIT 1

# DAMAGED COMPARTMENTS FOR CONDITION 5

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
5	74.000	95.000	0.950

## CONDITIONS AFTER DAMAGE

DISPLACEMENT	1262.198 TONS SW
LONGL C.G.	-1.960 FEET FROM AMIDSHIPS (+ FWD)
DRAFT AMIDSHIPS	11.401 FEET
DRAFT AT FP	11.247 FEET
DRAFT AT AP	11.554 FEET

TOTAL TRIM	0.306 FEET
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FLOODED WATER	231.198 TONS SW
LCG OF FLD.WTR.	-7.012 FEET FROM AMIDSHIPS (+ FWD)
SHIP-OSV	SERIAL NUMBER-

1 DATE-01-29-86

## TRIM LINE CALCULATIONS

# DAMAGED COMPARTMENTS FOR CONDITION 6

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
6	95.000	126.000	0.850

## CONDITIONS AFTER DAMAGE

DISPLACEMENT	1367.549 TONS SW
LONGL C.G.	-8.562 FEET FROM AMIDSHIPS (+ FWD)
DRAFT AMIDSHIPS	12.422 FEET
DRAFT AT FP	7.996 FEET
DRAFT AT AP	16.849 FEET

TOTAL TRIM	8.853 FEET
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FLOODED WATER	336.549 TONS SW
LCG OF FLD.WTR.	-32.256 FEET FROM AMIDSHIPS (+ FWD)
SHIP-OSV	SERIAL NUMBER-

1 DATE-01-29-86

# TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 7

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
7	126.000	142.000	0.850

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1101.799 TONS SW  
 LONGL C.G. -4.337 FEET FROM AMIDSHIPS (+ FWD)  
 DRAFT AMIDSHIPS 10.242 FEET  
 DRAFT AT FP 9.047 FEET  
 DRAFT AT AP 11.437 FEET

TOTAL TRIM 2.390 FEET

FLOODED WATER 70.799 TONS SW  
 LCG OF FLD.WTR. -55.444 FEET FROM AMIDSHIPS (+ FWD)  
 SHIP-OSV SERIAL NUMBER- 1

DATE-01-29-86

# TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 8

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
8	142.000	150.000	0.850

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1041.357 TONS SW  
 LONGL C.G. -1.496 FEET FROM AMIDSHIPS (+ FWD)  
 DRAFT AMIDSHIPS 9.912 FEET  
 DRAFT AT FP 9.591 FEET  
 DRAFT AT AP 10.233 FEET

TOTAL TRIM 0.641 FEET

FLOODED WATER 10.357 TONS SW  
 LCG OF FLD.WTR. -67.972 FEET FROM AMIDSHIPS (+ FWD)  
 SHIP-OSV SERIAL NUMBER- 1

DATE-01-29-86

# TRIM LINE CALCULATIONS

# DAMAGED COMPARTMENTS FOR CONDITION 9

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
9	150.000	155.000	0.100

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1031.325 TONS SW  
 LONGL C.G. -0.851 FEET FROM AMIDSHIPS (+ FWD)  
 DRAFT AMIDSHIPS 9.860 FEET  
 DRAFT AT FP 9.729 FEET  
 DRAFT AT AP 9.992 FEET

TOTAL TRIM 0.264 FEET

FLOODED WATER 0.325 TONS SW  
 LCG OF FLD.WTR. -74.979 FEET FROM AMIDSHIPS (+ FWD)  
 SHIP-OSV SERIAL NUMBER-

1 DATE-01-29-86

## TRIM LINE CALCULATIONS

# DAMAGED COMPARTMENTS FOR CONDITION 10

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
1	0.000	10.000	0.100
2	10.000	24.000	0.100

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1035.379 TONS SW  
 LONGL C.G. -0.568 FEET FROM AMIDSHIPS (+ FWD)  
 DRAFT AMIDSHIPS 9.895 FEET  
 DRAFT AT FP 9.860 FEET  
 DRAFT AT AP 9.930 FEET

TOTAL TRIM 0.071 FEET

FLOODED WATER 4.379 TONS SW  
 LCG OF FLD.WTR. 60.648 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER- 1 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 11

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
2	10.000	24.000	0.100
3	24.000	48.000	0.650

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1192.146 TONS SW  
LONGL C.G. 4.891 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 11.130 FEET  
DRAFT AT FP 13.479 FEET  
DRAFT AT AP 8.781 FEET

TOTAL TRIM -4.697 FEET

FLOODED WATER 161.146 TONS SW  
LLG OF FLD.WTR. 41.481 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER- 1 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 12

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
3	24.000	48.000	0.650
4	48.000	74.000	0.950

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1663.656 TONS SW  
LONGL C.G. 9.305 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 14.445 FEET  
DRAFT AT FP 20.336 FEET  
DRAFT AT AP 8.554 FEET

TOTAL TRIM 11.782 FEET

FLOODED WATER 632.656 TONS SW  
LLG OF FLD.WTR. 25.817 FEET FROM AMIDSHIPS (+ FWD)



SHIP-OSV

SERIAL NUMBER-

1

DATE-01-29-86

## TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 13

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
4	48.000	74.000	0.950
5	74.000	95.000	0.950

## CONDITIONS AFTER DAMAGE

DISPLACEMENT	1699.800 TONS SW
LONGL C.G.	2.022 FEET FROM AMIDSHIPS (+ FWD)
DRAFT AMIDSHIPS	14.546 FEET
DRAFT AT FP	16.950 FEET
DRAFT AT AP	12.141 FEET

TOTAL TRIM	-4.809 FEET
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FLOODED WATER	668.800 TONS SW
LCG OF FLD.WTR.	6.414 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER-

1

DATE-01-29-86

## TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 14

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
5	74.000	95.000	0.950
6	95.000	126.000	0.850

# DAMAGED COMPARTMENTS FOR CONDITION 1

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
6	95.000	126.000	0.850
7	126.000	142.000	0.850

## CONDITIONS AFTER DAMAGE

DISPLACEMENT	1473.833 TONS SW
LONGL C.G.	-11.948 FEET FROM AMIDSHIPS (+ FWD)
DRAFT AMIDSHIPS	21.647 FEET
DRAFT AT FP	-10.190 FEET
DRAFT AT AP	53.485 FEET
TOTAL TRIM	63.675 FEET
FLOODED WATER	442.832 TONS SW
LCG OF FLD.WTR.	-37.837 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

## TRIM LINE CALCULATIONS

# DAMAGED COMPARTMENTS FOR CONDITION 2

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
7	126.000	142.000	0.850
8	142.000	150.000	0.850

## CONDITIONS AFTER DAMAGE

DISPLACEMENT	1132.699 TONS SW
LONGL C.G.	-5.997 FEET FROM AMIDSHIPS (+ FWD)
DRAFT AMIDSHIPS	10.399 FEET
DRAFT AT FP	8.638 FEET
DRAFT AT AP	12.160 FEET
TOTAL TRIM	3.521 FEET
FLOODED WATER	101.699 TONS SW
LCG OF FLD.WTR.	-58.399 FEET FROM AMIDSHIPS (+ FWD)

SHIP-USV

SERIAL NUMBER-

2

DATE-01-29-86

## TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 3

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
8	142.000	150.000	0.850
9	150.000	155.000	0.100

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1041.880 TONS SW  
LONGL C.G. -1.532 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 9.914 FEET  
DRAFT AT FP 9.583 FEET  
DRAFT AT AP 10.246 FEET

TOTAL TRIM 0.663 FEET

FLOODED WATER 10.879 TONS SW  
LCG OF FLD.WTR. -68.246 FEET FROM AMIDSHIPS (+ FWD)

SHIP-USV

SERIAL NUMBER-

2

DATE-01-29-86

## TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 4

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
1	0.000	10.000	0.100
2	10.000	24.000	0.100
3	24.000	48.000	0.650

## CONDITIONS AFTER DAMAGE

DISPLACEMENT 1194.569 TONS SW  
LONGL C.G. 5.007 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 11.149 FEET  
DRAFT AT FP 13.553 FEET  
DRAFT AT AP 8.745 FEET

TOTAL TRIM -4.807 FEET

FLOODED WATER 167.569 TONS SW  
LCG OF FLD.WTR. 41.781 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 5

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
2	10.000	24.000	0.100
3	24.000	48.000	0.650
4	48.000	74.000	0.950

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1689.694 TONS SW  
LONGT C.G. 9.845 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 14.624 FEET  
DRAFT AT FP 20.890 FEET  
DRAFT AT AP 8.357 FEET

TOTAL TRIM -12.532 FEET

FLOODED WATER 658.694 TONS SW  
LCG OF FLD.WTR. 26.550 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 6

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
3	24.000	48.000	0.650
4	48.000	74.000	0.950
5	74.000	95.000	0.950

NO BALANCE

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 7

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
4	48.000	74.000	0.950
5	74.000	95.000	0.950
6	95.000	126.000	0.850

NO BALANCE

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 8

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
5	74.000	95.000	0.950
6	95.000	126.000	0.850
7	126.000	142.000	0.850

SHIP-DSV

SERIAL NUMBER-

2

DATE-01-29-86

## TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 1

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
1	95.000	126.000	0.850
2	126.000	142.000	0.850

## CONDITIONS AFTER DAMAGE

DISPLACEMENT	1473.85 TONS SW
CG OF DISC.	-11.948 FEET FROM AMIDSHIPS (+ FWD)
DEAF FROM AMIDSHIPS	21.647 FEET
DEAF FROM FP	-10.190 FEET
DEAF FROM AP	53.485 FEET
TOTAL TRIM	63.675 FEET
FLOODED WATER	442.832 TONS SW
CG OF FLD.WTR.	-37.837 FEET FROM AMIDSHIPS (+ FWD)

SHIP-DSV

SERIAL NUMBER-

2

DATE-01-29-86

## TRIM LINE CALCULATIONS

## DAMAGED COMPARTMENTS FOR CONDITION 2

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
2	126.000	142.000	0.850
3	142.000	150.000	0.850

## CONDITIONS AFTER DAMAGE

DISPLACEMENT	1132.699 TONS SW
CG OF DISC.	-5.997 FEET FROM AMIDSHIPS (+ FWD)
DEAF FROM AMIDSHIPS	10.399 FEET
DEAF FROM FP	8.678 FEET
DEAF FROM AP	12.160 FEET
TOTAL TRIM	3.521 FEET
FLOODED WATER	101.699 TONS SW
CG OF FLD.WTR.	-58.399 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 3

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
8	142.000	150.000	0.850
9	150.000	155.000	0.100

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1041.880 TONS SW  
LONGL C.G. -1.532 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 9.914 FEET  
DRAFT AT FP 9.583 FEET  
DRAFT AT AP 10.246 FEET

TOTAL TRIM 0.663 FEET

FLOODED WATER 10.879 TONS SW  
LCG OF FLD.WTR. -68.246 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 4

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
1	0.000	10.000	0.100
2	10.000	24.000	0.100
3	24.000	48.000	0.650

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1194.569 TONS SW  
LONGL C.G. 5.007 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 11.149 FEET  
DRAFT AT FP 13.553 FEET  
DRAFT AT AP 8.745 FEET

TOTAL TRIM -4.807 FEET

FLOODED WATER 163.569 TONS SW  
LCG OF FLD.WTR. 41.781 FEET FROM AMIDSHIPS (+ FWD)

SHIP-USV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 5

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
2	10.000	24.000	0.100
3	24.000	48.000	0.650
4	48.000	74.000	0.950

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1689.694 TONS SW  
LONGIT. C.G. 9.845 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 14.624 FEET  
DRAFT AT FP 20.890 FEET  
DRAFT AT AP 8.357 FEET

TOTAL TRIM -12.532 FEET

FLOODED WATER 658.694 TONS SW  
L.O.G. OF FLD.WTR. 26.550 FEET FROM AMIDSHIPS (+ FWD)

SHIP-USV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 6

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
	24.000	48.000	0.650
4	48.000	74.000	0.950
5	74.000	95.000	0.950

DISPLACEMENT



SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 7

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
4	48.000	74.000	0.950
5	74.000	95.000	0.950
6	95.000	126.000	0.850

NO BALANCE

SHIP-OSV

SERIAL NUMBER- 2 DATE-01-29-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 8

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
5	74.000	95.000	0.950
6	95.000	126.000	0.850
7	126.000	142.000	0.850

SHIP-OSV

SERIAL NUMBER-

4

DATE-01-28-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 1

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
7	126.000	142.000	0.850
8	142.000	150.000	0.850
9	150.000	155.000	0.100

CONDITIONS AFTER DAMAGE

DISPLACEMENT 1175.019 TONS SW  
LONGI C.G. -6.125 FEET FROM AMIDSHIPS (+ FWD)  
DRAFT AMIDSHIPS 10.411 FEET  
DRAFT AT FP 8.605 FEET  
DRAFT AT AP 12.217 FEET

TOTAL TRIM 3.612 FEET

FLOODED WATER 104.019 TONS SW  
LCG OF FLD.WTR. -58.631 FEET FROM AMIDSHIPS (+ FWD)

SHIP-OSV

SERIAL NUMBER-

4

DATE-01-28-86

TRIM LINE CALCULATIONS

DAMAGED COMPARTMENTS FOR CONDITION 2

COMPARTMENT NUMBER	FWD BULKHEAD FEET FROM FP	AFT BULKHEAD FEET FROM FP	PERMEABILITY
5	74.000	95.000	0.950
6	95.000	126.000	0.850

NUMBER	FEET FROM FP	FEET FROM FP	
7	126.000	142.000	0.850
8	<del>142.000</del>	150.000	0.850
9	<del>150.000</del>	155.000	0.100

# CONDITIONS AFTER DAMAGE

DISPLACEMENT	1135.019 TONS SW
LONGL C.G.	-6.125 FEET FROM AMIDSHIPS (+ FWD)
DRAFT AMIDSHIPS	10.411 FEET
DRAFT AT FP	8.605 FEET
DRAFT AT AP	12.217 FEET
TOTAL TRIM	3.612 FEET
FLOODED WATER	104.019 TONS SW

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